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Loading Functions for Assessment of Water Pollution From Nonpoint Sources

Midwest Research Inst.

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May 1976

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Methods for evaluating the quantity of water pollutants generated from nonpoint sources including agriculture, silviculture, construction, mining, runoff from urban areas and rural roads, and terrestrial disposal are developed and compiled for use in water quality planning. The loading functions, plus in some instances emission values, permit calculation of nonpoint source pollutants from available data and information.

Natural background was considered to be a source and loading functions were presented to estimate natural or background loads of pollutants.

Loading functions/values are presented for average conditions, i.e., annual average loads expressed as metric tons/hectare/year (tons/acre/year). Procedures for estimating seasonal or 30-day maximum and minimum loads are also presented. In addition, a wide variety of required data inputs to loading functions, and delineation of sources of additional information are included in the report.

The report also presents an evaluation of limitations and constraints of various methodologies which will enable the user to employ the functions realistically.

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SECTION 1.0

INTRODUCTION

The rates and magnitudes of discharges of pollutants from nonpoint sources do not relate simply to source characteristics or source-related parameters. Evaluation of the severity of this problem is hampered by the lack of tools to quantify pollutant loads, and scanty and imprecise data on the interrelationships between control measures and pollutant loads are a deterrent to formulation of control or regulatory strategies. This User's Handbook is the result of a program which had as one objective the development of nonpoint pollution loading functions for significant sources and significant pollutants.

The Handbook has two basic functions. First, it presents loading functions together with the methodologies for their use. Second, it presents some of the needed data, provides references to other sources of data, and suggests approaches for generation of data when available data are inadequate. A corollary function consists of assessments of the adequacies of functions and their supporting inventories of data, and an assessment as well of the extent to which pollutants and nonpoint sources are adequately covered.

A loading function, as the term is used here, is a mathematical expression which one uses to calculate the emission of a pollutant from a nonpoint source and discharge of the pollutant into surface waterways. For purposes of this Handbook, a substance becomes a pollutant only when it is deposited in surface waters. For example, the movement of sediment and nutrients from a corn field to the edge of the field does not qualify as pollutant discharge, even though the transport process may be an important part of the overall pollutant emission mechanism.

A source is a land area devoted reasonably exclusively to a specific use, which therefore can be treated as a unit with respect to land use practices and potential for pollutant discharges. A cornfield, a field of soybeans, a highway under construction, a mine, a forest, and a landfill are sources. Similarly, a group of cornfields is considered to be a source if practices from field to field are sufficiently uniform that an average set of data adequately describes the entire acreage.

A load is defined as the quantity of pollutant discharged to surface waters from the source per unit of time: load = kilogram BOD per source per day, etc. The loading function is the expression or equation which permits calculation of the load. The function has provisions for calculation of a load on a per hectare basis (or other suitable unit dimension), and total source load is calculated by multiplying the unit load by source size. Finally, all sources within an area of interest, such as a watershed or river basin, can be summed up to obtain the load of a particular pollutant discharged to the surface waters from all identified sources.

A tremendous variety and quantity of data are necessary for productive use of the loading functions. A small fraction of that body of data is included in this handbook, primarily in the appencices. The user is referred to other sources of data ranging from systematic compilations to the knowledge and judgment of local experts. The importance of the latter can hardly be overemphasized. These sources are delineated in succeeding sections as specific data needs arise for individual loading functions.

Essentially three categories of data are needed. One category is the information which describes the areal characteristics of a source: its location within a county, basin, state; its sizes, perhaps its dimensions; and its basic land use, i.e., row crops, construction of residences, solid waste disposal, and strip mining.

A second category of data is that which is characteristic of a source or area, independently of land use. This category includes data which describe agricultural productivity, water permeability, erodibility, and similar properties of soils; topographic features of the land; rainfall and runoff; and stream miles, locations, and stream densities.

The third category is the data which are needed to describe how a source is used. Examples are tillage methods and conservation practices, cropping patterns, quantities and schedule of pesticide use, irrigation flows, and population densities.

It may perhaps be construed from the above discussion that the loading functions are straightforward expressions or equation, matched by precise, well-documented data, and that calculations can be made by routine procedures with perhaps little discriminatory inputs of judgment by the user. This seldom is the case. A substantial fraction of the presentations of the following sections is devoted to procedural descriptions which should assist the user in using his or other local judgments and inputs, and instruct the user in the limits of applicability of the functions.

Emphasis is given to loading functions or estimating procedures which are generally useful from the standpoint of the depth, quality, and quantity of available data or information. For this reason the functions are in the main relatively simple and basic concepts, as opposed to theoretically oriented descriptions of physical, chemical, mechanical, and biological processes. Indeed, where necessary and appropriate, estimates and the rule of thumb approach are preferred to more rigid theoretical functions which suffer from the lack of key data.

The loading functions cover the following sources and pollutants:

Sources

- Agriculture: cropland, pasture and rangeland, irrigated land, woodland, and feedlots
- Silviculture: growing stock, logging, road building
- Construction: urban development and highway construction
- Mining: surface mining and underground mines
- Terrestrial disposal: landfill and dumps
- Utility maintenance: highways and streets, and deicing
- Urban runoff
- Precipitation
- Background sources: native forests, prairie land, etc.

Pollutants

- Nutrients: nitrogen and phosphorus
- Sediment
- Biodegradable organics
- Pesticides
- Salinity
- Radioactivity
- Mine drainage
- Metals
- Microorganisms

The definition of the term pollutant used in this document takes some liberties with current legal definitions (specifically various interpretations of the law) and with philosophical interpretations of what substances under what circumstances should be viewed as pollutants. Basically, a substance is termed a pollutant if it has been observed in nonbeneficial quantities or concentrations. The task of determining when a specific substance is present in nonbeneficial quantities is left to the user and to official interpretations of water quality regulations. Sediment exemplifies the "pollutant" which serves a very useful purpose at some optimum level.

The concept of natural background is both quite important and difficult to describe in universally acceptable terms. Furthermore, background levels of the polluting substances cannot be readily and precisely determined by current methods which treat this subject and the approaches proposed in this document are admittedly the object of controversy with regard to both the philosophy of the approach and the technical methodology. The importance attributed to natural background comes from the following: (a) background is often thought to represent the ideal environmental quality, and thus to represent the goal which we should strive to achieve, and (b) background accordingly is often thought to be a fundamental criterion for assessing the reasonableness of control measures and for evaluating the cost of control in relation to benefits. These are not necessarily self-evident truths. A notable case in point is the salinity in much of our natural waters at levels above those suitable for certain beneficial uses. Background is nevertheless a useful concept in that it serves as a point of reference for determining what might be reasonably achieved in water quality management, for establishing goals and objectives, and for identifying conditions or sources over which we may have little or no control, such as precipitation-borne nitrogeneous compounds. The use of background at such a point of reference is legitimate, as long as ones interpretation of background is not used as an excuse to indiscrimately set aside or ignore certain problems.

SECTION 2.0

GUIDELINES FOR USE OF THE HANDBOOK

2.1 INTRODUCTION

This handbook has been developed for use with data or information on record and accessible to the user. Some exceptions occur; that is, certain loading functions assume the capability on the part of the user to procure data by field and laboratory analysis or other on-site data procurement methods. Field sampling and analysis is suggested when data on record are inadequate, perhaps not in existence at all.

The handbook user should obtain and use the best data he can find. The best data usually are those which have been measured or developed locally. Such data can supplement the data or data sources recommended throughout the handbook, or it can be used in a complementary fashion, i.e., to help arrive at a range of values appropriate for the specific user area.

The user is encouraged to use functions which are more area specific than those presented in the handbook, to use research models if he is so inclined, and to adapt suggested methodologies so that they directly represent his area.

The information regarding loading functions and their use is presented in Sections 3.0 through 12.0 and in Appendices A through H. The texts of Sections 3.0 through 12.0 are devoted chiefly to descriptions of the functions themselves, of the terms within the functions, and of procedures for use of the loading functions. These sections contain certain tables and figures which either present data needed in the loading functions or which describe procedures for use of the loading functions. Lengthy compilations of data are for the most part presented in the appendices. In addition, the appendices contain certain types of background information and presentations of specific procedures which are essential but which do not fit conveniently in the discussions in Sections 3 through 12.0.

The following subsections present information on terminology, symbols, formulas, and procedures for use of the handbook. The loading functions themselves are presented together with definitions of terms in tabular form. The material presented in the remaining parts of this section should be consulted by the user to help him define his specific problem and to guide him to those parts of the handbook which he will use in calculating the emissions of nonpoint pollutants from his sources.

2.2 TERMINOLOGY, SYMBOLS AND FORMULAS

The terminology and symbols conform with some exceptions to standard symbols and terms. A broad range of subject matter is covered, and the symbols normally used in one area or discipline overlap or are in conflict with those of another. These conflicts were sometimes resolved; other times the best course was to keep the old and familiar terminology.

Equations and formulas for the most part avoid the abbreviated notation and symbolism typical of engineering or physical science equations, in favor of more cumbersome but more readily interpreted terms.

The term Y universally denoted pollutant load for a source. The usual symbols for basic parameters have been used almost without exception: Q for volume rate of water flow, runoff or streamflow; P for precipitation; C for concentration, etc. S uniformly denotes sediments. The majority of the terms and symbols used in the handbook are defined in the summary of loading functions presented in Section 2.4, and in the "Glossary" and "Symbols" given in the last part of the handbook. Miscellaneous symbols are defined as they occur throughout the text of Sections 3.0 through 12.0 and the appendices.

The general format of the equations or loading functions is shown in Section 2.4. Note that multiplication of one term by another is to be performed only if the two terms are separated by the dot (·) symbol. The parenthesis is not used to denote multiplication; it has been reserved for the function of separating and defining terms or symbols. Thus, $C(HM)_{BG}$ denotes "background concentration of heavy metal," and Y(RAD) "load of radiation."

2.3 PROCEDURE FOR USE OF THE HANDBOOK

Several basic steps are involved in estimation of pollutant loads. These are:

1. Establish the boundaries of the area under consideration, which will usually be a political or physical entity: an urban area, a watershed, a minor basin, a state, etc. Define the general character of the area: agriculture, silviculture, mining, urban, etc.

2. Identify nonpoint sources in the area, in appropriate detail. Identify pollutants to be evaluated for each source. The source-pollutant matrix, Table 2-1, will assist in defining sources and pollutants.

3. Identify loading function options: Section 2.4 and Sections 3.0 through 12.0.

4. Identify data needs, determine availability of data for possible options; assess quality and depth of coverage of available data: Sections 3.0 through 12.0 and Appendices A through H.

5. Select loading functions which best match the problem with quality and depth of data.

6. Procure necessary data for all sources/pollutants.

7. Calculate pollutant loads (see Sections 3.0 through 12.0) for individual sources, and sum to obtain total loads.

2.4 SUMMARY OF LOADING FUNCTIONS

In this section approaches to calculation of pollutants are summarized. Limitations to their use are presented as well, in summary fashion. Pollutants and sources which must be treated by approximate methods which require much discretion in use are delineated.

The summary cites no references. These are cited in Sections 3.0 through 12.0 and the appendices. References to tables, figures, and equations in Sections 3.0 through 12.0 are provided to facilitate location of methods and procedures, together with detailed discussion of dimensional units.

2.4.1 Sediment From Sheet and Rill Erosion

The basic tool for estimation of sediment from sheet and rill erosion is the Universal Soil Loss Equation (USLE). The loading function based on the USLE is:

Table 2-1. SOURCE - POLLUTANT MATRIX[a]

Source	Pollutant								
	Sediment	Nutrient N, P	Organic matter BOD	Pesticides H,I,F	Salinity TDS	Heavy metals	Radioactivity	Coliform	Other
Agriculture	3	4	4	5		8			
Irrigation return flow					6				
Silviculture	3	4	4	5		8			
Mining	3					8	8		Acid mine drainage - 7
Construction	3					8			
Urban runoff	9	9	9	9	9	9		9	
Highways	9	9	9		9	9			
Feedlots	10	10	10					10	Suspended solids - 10
Terrestrial disposal		11[b]	11		11	11			
Background	12	12	12		12	12	12	12	

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[a] Numbers in table indicate section numbers.
[b] Nitrogen only.

$$Y(S)_E = A\cdot(R\cdot K\cdot L\cdot S\cdot C\cdot P\cdot S_d) \tag{3-1}$$

where $Y(S)_E$ = sediment loading

A = source area

R = the rainfall factor; Figures 3-2 and 3-3, or methods presented in Section 3.2

K = the soil erodibility factor; USDA K factor lists, Appendices B, D, and E

L = the slope length factor; Figures 3-7, 3-8, and 3-9, Appendices C, D, and E

S = the slope gradient factor; Figures 3-7, 3-8, and 3-9, Appendices C, D, and E

C = the cover factor; USDA C factor lists, Tables 3-3 to 3-6

P = the practice factor, Table 3-7

S_d = sediment delivery ratio, Eq. (3-2), Figure 3-10

The USLE was developed primarily for agriculture, and has been used chiefly east of the Rocky Mountains. The factors are best defined for these areas of use, and methods for use in silviculture, construction, mining, and other sources outside agriculture are not well developed. For the latter sources the USLE can serve as the basis for estimations by personnel skilled in soil science and hydrology. The USLE is quite useful in areas outside agriculture for estimating the probably impact of control measures (dikes, vegetation, slope modification), even though it may be inaccurate for estimation of absolute values for sediment yields, especially from small subwatersheds.

2.4.1.1 Streambank and gully erosion (see Section 3.0) -

Streambank and gully erosion are not treated by the USLE, and landslides are similarly not treated. Calculation of sediment yields from these sources requires examination of experience and data in the area of interest, by local personnel.

2.4.1.2 Sediment from urban runoff -

Methods for estimating sediment in urban runoff are presented in Section 9.0 (see 2.4.7). The basic method involves the use of values for various urban areas developed by analysis of sediment loads in many urban areas.

2.4.1.3 Sediment from feedlots (see Section 10.0) -

The Universal Soil Loss Equation is not used for feedlots. Measured data on feedlot runoff are used as the basis for prediction. Feedlot loading functions are synopsized in Section 2.4.8.

2.4.2 Nutrients and Organic Matter (see Section 4.0)

The principal method of estimating nutrient and organic matter loads consist of first calculating sediment yields, and multiplying sediment yields by factors which denote concentrations of these substances in the soil and enrichment in the erosion process.

2.4.2.1 Nitrogen -

Yields of total nitrogen (NT, all forms of nitrogen) are estimated by multiplying sediment yields by concentrations of total nitrogen in soil and by an enrichment factor. In addition to sediment-carried nitrogen, nitrogen carried in rainfall is included in the loading function. Available nitrogen is the sum of precipitation-borne nitrogen and a fraction of the sediment-borne nitrogen.

$$Y(NT)_E = a \cdot Y(S)_E \cdot C_S(NT) \cdot r_N \tag{4-1}$$

$$Y(N)_{Pr} = A \cdot \frac{Q(OR)}{Q(Pr)} \cdot N_{Pr} \cdot b \tag{4-3}$$

$$Y(NT) = Y(NT)_E + Y(N)_{Pr}$$

$$Y(NA) = Y(NT)_E \cdot f_N + Y(N)_{Pr} \tag{4-4}$$

where $Y(S)_E$ = sediment load

$Y(NT)_E$ = total nitrogen from erosion

$Y(N)_{Pr}$ = nitrogen from rainfall, discharged to streams

NT = sum of nitrogen of all chemical forms

A = area of source

r_N = enrichment factor

NA = available (mineralized) nitrogen

f_N = ratio of NA to NT in sediment

a = dimensional constant

b = attenuation factor

N_{Pr} = rate of deposition of nitrogen from the atmosphere in precipitation

$C_S(NT)$ = concentration of nitrogen in soil

Q(OR) = overland runoff

Q(Pr) = total precipitation

"Available nitrogen" is the forms of nitrogen which are readily available for plant nutrition: nitrate, ammonia, and simple amines. Essentially all of the nitrogen in rainfall is in the available form.

The loading functions for nitrogen based on the USLE and presented in Section 4.0 do not apply to nitrogen from certain specific sources.

Nitrogen from terrestrial disposal operations, presented in Section 11.0 (see 2.4.9) is estimated by procedures for estimating leachate volumes, pollutant concentrations in leachates, and delivery ratios for leachates.

Nitrogen from feedlots, presented in Section 10.0 (see 2.4.8) is estimated from runoff volumes and a range of observed nitrogen concentrations.

Nitrogen in urban runoff, presented in Section 9.0 (see 2.4.7) is estimated from data on urban runoff characteristics.

The loading functions for nitrogen do not encompass soluble nitrogen forms, principally nitrate, which are leached into subsurface waters and eventually reach surface waters in groundwater or drainage flows. Methods for treating such situations via a generalized function are not available, and local experience, data and expertise must be relied upon.

The loading functions for nitrogen based on sediment as a carrier become increasingly inadequate as sediment yields diminish. This inadequacy will be most evident in situations where erosion is minimal and mineralized nitrogen is abundant. A newly harvested forest temporarily devoid of growing timber may have a temporary excess of mineralized nitrogen which is susceptible to both leaching and transport overland in sediments and in solution. Nitrogen emissions from terraced fields may be higher in mineralized nitrogen than emissions from fields with less control of runoff and erosion.

2.4.2.2 Phosphorus -

Functions for phosphorus are presented in:

Section 4.0, Nutrients and Organic Matter;
Section 9.0, Urban Runoff; and
Section 10.0, Livestock in Confinement.

Refer to Sections 2.4.7 and 2.4.8 for a summary of functions for phosphorus in urban runoff and feedlot runoff. Functions for sediment-borne nutrients from other sources are presented below.

Phosphorus is carried almost entirely on sediment. In situations where erosion can be predicted, the loading function for phosphorus can be expressed as the product of sediment yield times phosphorus concentration in sediment. The concentration of phosphorus is taken to be the concentration in the eroding soil times an enrichment factor.

The load of available phosphorus is calculated by multiplying the load of total phosphorus by the ratio of available phosphorus to total phosphorus.

$$Y(PT) = a \cdot Y(S)_E \cdot C_S(PT) \cdot r_P \tag{4-8}$$

$$Y(PA) = Y(PT) \cdot f_P \tag{4-9}$$

where $Y(PT)$ = yield of total phosphorus

a = dimensional constant

$C_S(PT)$ = concentration of phosphorus in soil

r_P = enrichment factor

$Y(PA)$ = yield of available phosphorus

f_P = ratio of available phosphorus to total phosphorus

2.4.2.3 Organic matter -

Functions for organic matter (BOD) are presented in:

Section 4.0, Nutrients and Organic Matter;
Section 9.0, Urban Runoff (see Section 2.4.7); and
Section 10.0, Livestock in Confinement (see Section 2.4.8).

Essentially all nonpoint emissions of organic matter are sediment borne. Organic matter loading functions are expressed as a function of sediment yields, with the exception of feedlot runoff, where a range of concentrations in runoff is used to calculate loads. For other nonurban sediment and for urban sediments, the yield of organic matter is a product of sediment yield and organic matter concentration in sediment; an enrichment factor is needed to account for preferential erosion of organic-rich sediments in nonurban sources.

$$Y(OM)_E = a \cdot C_S(OM) \cdot Y(S)_E \cdot r_{OM} \qquad (4\text{-}12)$$

where $Y(OM)_E$ = organic matter loading

$Y(S)_E$ = total sediment loading from surface erosion (see Eq. (3-1))

r_{OM} = enrichment factor

a = dimensional constant

$C_S(OM)$ = organic matter content of soil

Loads of organic matter calculated by procedures in the handbook cover major known sources, except for special cases which are not amenable to treatment by generalized functions. Some of these are:

Direct or wind-blown deposition in streams of leaves from forests.

Capture of hay and other vegetative debris by floodwaters.

Irresponsible dumping of livestock wastes or other organic wastes in sites susceptible to washout or erosion (including improper field spreading of manure).

2.4.3 Pesticides

Loading functions for pesticides are among the least satisfactory of those presented in the handbook.

In one option (Case I Method, Section 5.0) national historical data on concentrations of pesticides in soils are the basis for estimation. These concentrations are multiplied by sediment yields to calculate pesticide loads. The method is restricted to insoluble pesticides. A major drawback of the approach is its insensitivity to peak loads which may occur during the pesticide use season at times of high runoff. The method also suffers (presently) from a relative scarcity of data on soil concentrations. It is useful primarily for large areas (states, major basins) where average yields may be adequate, and small watershed specific loads are not required.

2.4.3.1 Insoluble pesticides, Case I and Case II methods -

$$Y(HIF) = Y(S)_E \cdot C_S(HIF) \cdot r_{HIF} \cdot 10^{-6} \qquad (5\text{-}1)$$

where $Y(HIF)$ = total pesticide loading for source

$Y(S)_E$ = sediment loading, Eq. (3-1)

$C_S(HIF)$ = concentration of pesticide in soil

r_{HIF} = enrichment ratio

The adequacy and applicability of the above method may be increased substantially through inputs of local/regional data and experience on pesticide usage, levels in soils, rainfall and runoff patterns in relation to pesticide use, and data on persistencies (life times) of pesticides in the use environment. The Case II method for insoluble pesticides is based on losses in sediments, as in the Case I method, with liberal inputs of local data.

2.4.3.2 Soluble plus insoluble pesticides (Case III method) -

A Case III method is presented, in Section 5.0, for both soluble and insoluble pesticides, which requires that local data be obtained on runoff and on pesticide concentrations in runoff. If historical data of this type are available it may be used for predictive purposes. If none are available, data accumulated in a sampling program in the area or region of concern will serve as the basis for development of a predictive capability.

$$Y(HIF) = \sum_{i} Q_i C_i \cdot a \qquad (5\text{-}2)$$

where Q = runoff volumes

C = concentration in runoff

i = storm event

a = dimensional constant

2.4.4 Salinity in Irrigation Return Flow

Three optional methods are presented in Section 6.0 for estimating salinity in irrigation return flow. Each of the options is valid in principle but has drawbacks due to one or more of the following reasons: (a) data inputs are not readily accessible; (b) the quality of existing data inputs varies widely; and (c) a good deal of insight about specific cases is required on the part of the user. At the present time, a good bit of effort is underway to develop mathematical models for salinity in irrigation return flow. It is reasonable to expect that outputs from these models will yield loading functions which will supercede the three methods presented in this handbook.

The three methods are:

Option I: Calculation of Water and Salt Balances About the Irrigation Site

$$Y(TDS)_{IRF} = a \cdot A \cdot C(TDS)_{GW} \cdot [IRR + Pr - CU] \qquad (6\text{-}1)$$

where $Y(TDS)_{IRF}$ = salinity load in irrigation return flow

A = irrigated area

IRR = irrigation water added to crop root annually

Pr = annual precipitation

CU = annual water consumptive use

$C(TDS)_{GW}$ = concentration of total dissolved solids in groundwater contributing to subsurface return

a = conversion factor

Option II: Salt Balances in Streamflow

$$Y(TDS)_{IRF} = a \cdot [Q(Str)_B \cdot C(TDS)_B - Q(Str)_A \cdot C(TDS)_A] - Y(TDS)_{BG} - Y(TDS)_{PT} \quad (6\text{-}4)$$

where $Y(TDS)_{IRF}$ = salinity load contribution from irrigation

$Y(TDS)_{BG}$ = salinity load contribution of background

$Y(TDS)_{PT}$ = salinity load contribution of point sources

$Q(Str)_B$ = streamflow below irrigated areas

$Q(Str)_A$ = streamflow above irrigated areas

$C(TDS)_B$ = total dissolved solids concentration below irrigated area

$C(TDS)_A$ = total dissolved solids concentration above irrigated area

a = conversion constant

Option III: Estimation From Historical Data

Loads from several irrigated areas have been quantitatively assessed over a period of years. These data, synopsized in Tables 6-3 through 6-7, and other data available to the user, can serve as guidelines for current estimations of salinity in irrigation return flows.

Option I requires specific information concerning how much water is delivered, how much is used consumptively, and the concentration of salt in groundwater where applied irrigation water may be lost by deep percolation. Uncertainty in any of these input data will affect the accuracy of the procedure. Option I is most realistic in cases where the groundwater dissolved solids are several times higher than dissolved solids in applied irrigation water, and is recommended for use in those areas meeting such a specification. Furthermore, the procedure is not recommended for sprinkler irrigation systems where evaporative losses in the delivered water may be excessive.

Option II has been the method traditionally used to estimate salinity from irrigation return flow. Basically, this method consists of measuring salinity loads in streams above and below irrigated areas. Differences in salinity are thus attributed to irrigation. The principle uncertainty in the Option II method lies in the contribution of background to the salinity load. Definition of background salinity will require knowledge and insight about the particular area being considered.

Option III--loading values--is perhaps the most reliable method. However, loading values must have been determined for the area of interest or for like areas in order for the method to be useful. Such values are not available in many irrigated areas. The measurement of salinity loads requires extensive monitoring and analysis, which are beyond the resources of many irrigation projects. As mathematical models are developed for predicting salinity from irrigation return flow, it is likely that their outputs can be used to obtain valid estimates of salinity loading values from specific areas.

2.4.5 Acid Mine Drainage

Two options are presented for acid mine drainage emissions to surface waters--source to stream approach, and stream to source approach. The loading functions are discussed in Section 7.0 of the handbook.

Source to stream approach - The source to stream loading function has been developed based upon statistical analysis of acid mine drainage data in the Monongahela River Basin. The loading function describes the potential acid formation from a "typical" mine, and allows for the neutralization of part of the acid by background alkalinity. Definition of the typical mine was established by regression analysis. The source to stream loading function is:

$$Y(AMD) = N[K_a \cdot (I_{AU} + I_{IU} + I_{AS} + I_{IS}) - K_b \cdot Q(R) \cdot C(Alk)_{BG}] \quad (7\text{-}1)$$

where $Y(AMD)$ = acid mine drainage load

N = total number of sources which are potential emitters of mine drainage

$I_{AU}, I_{AS}, I_{IU}, I_{IS}$ = load index values, Table 7-2

K_a, K_b = constants determined from regression analysis, Table 7-1

$Q(R)$ = flow as annual average runoff

$C(Alk)_{BG}$ = concentration of background alkalinity, Figure 7-1

This loading function depends upon knowledge of the numbers of mines in various categories (underground and surface, active and inactive) and upon the neutralization potential of background. It should be applicable to all mines associated with pyritic wastes whether they be coal or metal ore mines. There is a good deal of uncertainty in its application to metal mines, since the function was developed for the Appalachian coal regions of the United States, and becomes less accurate as one moves westward into coal areas of the midwest and west.

Stream to source approach - The stream to source loading function for acid mine drainage is based upon comparison of sulfate loadings in streams to sulfate contributions from background and from point sources. The rationale for this approach lies in the fact that sulfate is a principal product of acid mine drainage. The loading function is:

$$Y(AMD) = a \cdot A \cdot Q(R)[C(SO_4) - C(SO_4)_{BG} - C(SO_4)_{PT}] \qquad (7\text{-}8)$$

or $$Y(AMD) = a \cdot Q(Str)[C(SO_4) - C(SO_4)_{BG} - C(SO_4)_{PT}]$$

where $Y(AMD)$ = acid mine drainage

A = area containing mine drainage sources

$Q(R)$ = flow as annual average runoff

$Q(Str)$ = flow as streamflow

$C(SO_4)$ = sulfate concentration in surface waters

$C(SO_4)_{BG}$ = sulfate concentration in surface waters attributable to background, Figure 7-2

$C(SO_4)_{PT}$ = sulfate concentration from point sources

a = dimensional constant

The stream to source approach does not allow for neutralization of acid mine drainage between the point where it is formed and the point where it is discharged. Thus, high values may be estimated in some cases.

The main uncertainty in the function is contribution of sulfate from background and point sources. Knowledge of the area under consideration is essential for accuracy. If the function is used in primarily rural areas, the point source sulfate contribution term can be ignored.

2.4.6 Heavy Metals and Radiation (see Sections 8.0, 9.0 and 11.0)

Nonpoint sources of heavy metals and radiation include sediment, abandoned mine sites, chat piles, tailings piles, urban runoff, and landfill.

Methods for estimation of emissions of heavy metals from urban runoff and landfill are presented in Sections 9.0 and 11.0 (see 2.4.7 and 2.4.9), respectively. Methods for estimation of loads from mines and mining refuse are presented in Section 8.0. The latter methods are summarized below.

In general, methods for calculating loads of heavy metals and radioactivity are relatively crude. Their principal usefulness likely is limited to pinpointing of problem areas, so that needs for analysis in greater depth can be determined.

One option for estimation of loads assumes that data on individual sources are available, and can be summed to a total load (Option I below). A second option assumes no source data are available and historical data (or handbook user-generated data) on streamflow or runoff and on concentrations of the pollutants in the flows are compared with information on background levels of the pollutants (Option II below).

The special case of heavy metals associated with sediment emissions is considered in Section 8.5.

Option I: Summation of Loads From Individual Sources

$$Y(HM, RAD) = a \cdot \sum_{n} Q_n \cdot C(HM, RAD)_n \qquad (8\text{-}1) \text{ and } (8\text{-}2)$$

where $Y(HM, RAD)$ = heavy metal (HM) load or radioactivity (RAD) load

$C(HM, RAD)_n$ = heavy metal or radioactivity concentration emitted from the n^{th} source

Q_n = flow from the n^{th} source

a = conversion factor, Table 8-1

Option II: Estimation From Data on Runoff or Streamflow

$$Y(HM,\ RAD) = a \cdot A \cdot Q(R) \cdot [C(HM,\ RAD) - C(HM,\ RAD)_{BG}] \quad (8\text{-}3) \text{ and } (8\text{-}5)$$

or $$Y(HM,\ RAD = a \cdot Q(Str)[C(HM,\ RAD) - C(HM,\ RAD)_{BG}] \quad (8\text{-}4) \text{ and } (8\text{-}6)$$

where $Y(HM, RAD)$ = heavy metal (HM) load or radioactivity (RAD) load

$C(HM, RAD)$ = concentration of heavy metal or radioactivity in runoff or streams

$C(HM, RAD)_{BG}$ = heavy metal or radioactivity concentration emitted from background, Figures 8-1 through 8-7

A = area containing nonpoint sources

$Q(R)$ = flow as average annual runoff

$Q(Str)$ = flow as streamflow

a = conversion constant, Table 8-3

Heavy Metals Attached to Sediment

The special case of heavy metals in the soil matrix carried into surface waters with sediment is treated by the following method. The method is discussed in detail in Section 8.5.

$$Y(HM)_S = a \cdot C_S(HM) \cdot Y(S)_E \qquad (8\text{-}7)$$

where $Y(HM)_S$ = yield of heavy metals in sediment

$C_S(HM)$ = concentration of heavy metals in the eroded soil

$Y(S)_E$ = sediment yield as defined by Eq. (3-1).

a = conversion factor

2.4.7 Urban and Related Sources (see Section 9.0)

An extensive amount of data have been assembled and evaluated in several recent studies. These data comprise loading values for pollutants in urban and highway runoff. Pollutants documented include solids (sediment), BOD, COD, phosphorus, nitrate, ammonia, coliforms, organic nitrogen, and heavy metals.

The loading functions are summarized below. The data on which the functions are based have been analyzed for standard error, which usually is relatively low (< ± 50%). Discretion must be exercised in extrapolations to urban areas for which no data exist.

2.4.7.1 Urban runoff -

Solids

$$Y(S)_U = L(S) \cdot L_{st} \qquad (9\text{-}1)$$

where $Y(S)_U$ = solid loading from urban nonpoint sources

$L(S)$ = solid loading rate, Table 9-1

L_{st} = street curb-length

Other pollutants

$$Y(i)_U = a \cdot Y(S)_U \cdot C(i)_U \qquad (9\text{-}2)$$

where $Y(i)_U$ = loading of pollutant i from urban nonpoint sources

a = dimensional constant

$Y(S)_U$ = urban solid loading

$C(i)_U$ = concentration of pollutant i in solids, Tables 9-1 and 9-2

2.4.7.2 Road traffic -

$$Y(i)_{tr} = Y(i) \cdot LH \cdot TD \cdot AX \qquad (9\text{-}4)$$

where $Y(i)_{tr}$ = loading of pollutant i from road traffic

$Y(i)$ = deposition rate of pollutant i, Table 9-5

LH = length of highway

TD = traffic density

AX = average number of axles per vehicle

2.4.7.3 Street and highway deicing salts -

$$Y(DI) = a \cdot b \cdot DI \qquad (9\text{-}5)$$

where $Y(DI)$ = salt loading

a = dimensional constant

b = attenuation factor

DI = amount of deicer applied, Appendix H

2.4.8 Livestock in Confinement (see Section 10.0)

Data on ranges of concentrations of pollutants in feedlot runoff have been combined with methods for estimating runoff quantities from feedlots. The overall methodology is crude, and differences between actual and estimated loads may be great. The precision of the estimates is also dependent on the accuracy of information on feedlot locations, areas, and sizes. Feedlots with runoff control are excluded from the nonpoint category.

Pollutants covered are sediment, BOD, phosphorus, nitrogen, and coliforms.

$$Y(i)_{FL} = a \cdot Q(FL) \cdot C(i)_{FL} \cdot FL_d \cdot A \qquad (10\text{-}1)$$

where $Y(i)_{FL}$ = loading rate of pollutant i from a livestock facility

a = a constant

$Q(FL)$ = direct runoff from feedlots

$C(i)_{FL}$ = concentration of pollutant i in runoff, Tables 10-1 and 10-2

FL_d = delivery ratio, feedlots

A = area of livestock facility

2.4.9 Terrestrial Disposal

Leachates from wastes disposed on land vary widely in quantity and composition, and delivery of leachate-contained pollutants to surface waters may range from 0 to 100%. The loading function for these pollutants is thus very crude, and reasonably accurate results depend greatly on the availability of site-specific information. The handbook presents synopses of data on pollutant concentrations in leachates, and suggests a general methodology which should be adapted to local or regional needs.

The loading function requires knowledge either of percolating or leachate rates, information on pollutant concentration, and knowledge of site characteristics which permit estimation of a delivery ratio.

$$Y(i)_{LF} = a \cdot C(i)_{LF} \cdot Q(LF) \cdot LF_d \cdot A \qquad (11\text{-}1)$$

where $Y(i)_{LF}$ = loading rate of pollutant i

a = dimensional factor

$C(i)_{LF}$ = concentration of pollutant i in leachate at site, Table 11-1

$Q(LF)$ = percolation rate (Figure 11-2)

LF_d = leachate delivery ratio

A = area of landfill

2.4.10 Background Emissions of Pollutants (see Section 12.0)

Stream to source approach - The background, or "natural" rates of pollutant emissions is a sensitive, controversial area. One approach to definition and estimation of background loads is based on the National Hydrologic Benchmark Network. Iso-pollutant maps for various pollutants have been developed from the Network data. These may be used to deduce probable "natural" in-stream pollutant concentrations, or to estimate delivered loads.

$$Y(i)_{BG} = a \cdot A \cdot Q(R) \cdot C(i)_{BG} \qquad (12\text{-}1)$$

$$\text{or} \quad Y(i)_{BG} = a \cdot Q(Str) \cdot C(i)_{BG} \qquad (12\text{-}2)$$

where $Y(i)_{BG}$ = load of background constituent i

a = conversion factor, Tables 12-1 and 12-2

A = watershed area

$Q(R)$ = flow as average annual runoff

$Q(Str)$ = flow as streamflow

$C(i)_{BG}$ = estimated concentration of background constituent i, Figures 12-1 through 12-18, Tables 13-1 and 13-2, and Figures 13-1 and 13-2

The iso-pollutant maps will not adequately represent many local, site-specific, problem areas. Background concentrations and loads should in such cases be deduced from local, site-specific data.

Source to stream approach - Where a "natural" condition can be defined, it is in principal possible to calculate background loadings via use of loading functions for a specific pollutant. In Section 12.3 is presented a method for calculating natural nonpoint emissions of sediment. The method may be extended to phosphorus, total nitrogen, BOD, and heavy metals. It consists of calculation of sediment yields from a natural site, namely, land with a vegetative cover typical of that which existed before man changed that condition.

$$Y(S)_{BG} = Y(S)_{E} \text{ from Eq. (3-1) for natural conditions}$$

$$Y(NT)_{BG} = C_s(NT)_{BG} \cdot Y(S)_{BG} \cdot r_N \cdot a$$

$$Y(PT)_{BG} = C_s(PT)_{BG} \cdot Y(S)_{BG} \cdot r_P \cdot a$$

r_N, r_P = enrichment ratios

$C_s(NT)$ = concentration of nitrogen in soil

$C_s(PT)$ = concentration of phosphorus in soil

a = dimensional constant

2.5 LIMITATIONS AND ACCURACIES

The estimation of nonpoint pollution is an approximate science, in its present stage of development. In some instance the term science is not appropriate. The loading functions presented in this handbook should be adopted and used with this understanding. In not one case does a function cover all possible variables and all possible situations. Particularly lacking is the capability to follow a dynamic, hour by hour event or a day by day situation, and develop an integrated load curve which reflects changes with time. In nearly all cases scientific methods will permit reasonably accurate measurement of gross processes in a dynamic event, e.g., a rainstorm with its accompanying overland runoff and transport of pollutants. It is not the purpose of this handbook, however, to present the detail of measurement methodologies, for the objective of the work has been to provide a methodology which will permit estimation of nonpoint pollutant emissions with a minimum of field measurement and will be dependent primarily on existing data and information.

The lack of scientifically derived expressions (or even valid empirical relationships) has led to the development of estimating procedures based on averaged data. In only one case--soil loss--has the accumulated data been developed into a currently useful load equation based on parameters which represent the physical phenomena involved in generation and transport of the pollutant. The Universal Soil Loss Equation (USLE) represents long term average on an annual basis. It can be used to predict an assumed single storm event or a series of storm events, but factor values for single events or for seasonal events are not as complete and available as "annual average" factors. If one is interested in extremes over a period of years, i.e., the equivalent of 7 day-10 year flow, factor values are essentially nonexistent.

The program which generated this handbook has "piggy-backed" the USLE to formulate loading functions for nitrogen, phosphorus, organic matter, and certain pesticides under certain conditions. These functions thus are based on the well established USLE factors and on an extensive body of data relating to the specific pollutants. Again, the functions are better for average conditions than for extremes.

The above discussion illustrates a key point regarding the accuracies and limits of usefulness of the loading functions presented in this handbook. The technology is usually adequate to reasonably good for predicting averaged pollutant loads. The spread or range of values which make up that average is likely to be high, however, and an estimated accuracy which includes the probable actual extreme loads about the calculated average will therefore be much worse than the accuracy in predicting the average. The estimates of accuracies presented in Sections 3.0 to 12.0 for the most part are our estimates of the capability of the loading function to predict an average load, whether it be an "annual average" or a "30 day-maximum average." The user should recognize that any specific real year may be quite atypical with regard to rainfall quantities, intensities, runoff, vegetative cover and other factors, and that the actual load may be well outside the specified accuracies.

It should be emphasized that sufficient data are simply not available for statistically valid estimation of accuracies. The reported accuracies are generally best estimates based on characteristics of the function, its required data base, and the reported/observed ranges of loads of various pollutants.

Worthy of special mention is the fact that good, area-specific input data will give much better results than nonspecific or haphazardly selected data.

Some nonpoint sources are not amenable to treatment by loading functions, for one or more of several reasons: (1) the source may be so irregular in occurrence that it can only be described by local personnel;

(2) data on loads may be lacking; and (3) the source itself cannot be described in terms which can be translated into rates of pollutant emission. A list of sources and pollutants which fall in this category follows:

- Roadside erosion
- Gully erosion
- Landslide, creep
- Streambank erosion
- Improper manure spreading or dumping
- Bacteria from nonurban areas, excepting feedlots
- Direct deposition of vegetation in surface waters: leaf fall, wind blown organic matter
- Floodwater transport of floodplain debris
- Floodwater scouring of floodplains
- Salt leakage from oil fields
- Drainage-borne pollutants: forests, wetlands, agricultural lands
- Nutrients in irrigation return flow
- Groundwater contamination with nitrates, metals, bacteria, pesticides
- Direct deposition of fertilizers and pesticides in surface waters
- Improper disposal of construction and demolition debris
- Nonregulated, unauthorized dumping of domestic and industrial wastes

The loading functions and associated guidelines presented in the handbook vary considerably in sophistication, overall adequacy, demands for data collection, and requirements for local judgments, technical skills, and other resources. Nothing really constructive can be gained by ranking them by order of adequacy or by other yardsticks, and the limitations of each have been pointed out throughout the test. It is appropriate to point out a situation or two which currently present difficult challenges.

Perhaps the greatest void consists of the lack of a capability to systematically describe the movement of pollutants through the earth, from surface soil into the root zone, to storage in soil and subsoil moisture, into near surface and deep aquifers, and movement from thence to the surface as drainage and baseflow in streams. The transport of pollutants via these processes is little understood. Nitrate movement via subsurface routes is inadequately dealt with by current technology, and is essentially excluded from the loading functions. Metals, salts, bacteria, and soluble organic materials are treated generally with marginally adequate procedures; landfill leachate movement is a case in point. Treatment of irrigation return flow, and its load of salts, nutrients, etc., is a particularly difficult problem; this problem is better described than are like problems simply because it has been extensively and capably studied and monitored.

SECTION 3.0

SEDIMENT FROM SOIL EROSION

3.1 INTRODUCTION

The sediment produced by erosion of sloping lands, gullies, and streambanks, and transported to surface water is generally recognized as the greatest single pollutant from nonpoint sources. Sediment reduces water quality and often degrades deposition areas. Sediment occupies space needed for water storage in reservoirs, lakes, and ponds; restricts streams and drainageways; alters aquatic life and reduces the recreational and consumptive use value of water through turbidity. More importantly, sediment, particularly that produced from eroded topsoil, also carries other water pollutants such as nitrogen, phosphorus, organic matter, pesticides and pathogens.

Erosion of soil by water can take a variety of forms. Sheet erosion is the uniform removal of a thin layer of soil, normally by the impact of falling raindrops. Channel erosion exists as rill erosion, gully erosion, and streambank erosion, caused by detachment and transportation of sediment by flowing streams (channels) of water. Rill erosion is the result of soil removal by small concentrations of surface water, such as that often found between the rows of cultivated crops planted up and down slopes. Channels formed in rill erosion are small enough to be smoothed completely by cultivation methods.

Gully erosion, similar to rill erosion, is also caused by temporary concentration of surface runoff. However, erosion by gullying cuts, by definition, deeply enough into soil/subsoil that channels so formed cannot be smoothed completely by ordinary tillage tools.

Streambank erosion refers to carrying off of the soil material on the sides of a permanent streambed, including those with intermittent flow, by the energy of moving water.

Sediments are also produced from mass soil movement, which is the downslope movement of a portion of land surface under the effect of gravity. Such movements may take the form of landslide, mudflow, or downward creep of an entire hillside.

This section presents methods for assessing sediment loading from various sources. Sheet erosion and rill erosion are treated together as surface erosion in Section 3.2; the remaining are presented in Section 3.3.

3.2 SEDIMENT LOADING FROM SURFACE EROSION

3.2.1 Overview

In general, the most important contributor of sediment nationwide is surface erosion. Erosion agents, including water, wind, and rain splash, work continuously to break down the earth's surface to produce sediment from cropland, forests, pastures, construction sites, mining sites, road rights-of-way, etc.

The basic mechanisms of soil erosion by water consist of: (a) soil detachment by raindrops; (b) transport by rainfall; (c) detachment by runoff; and (d) transport by runoff.[1/] The damage caused by raindrops hitting the soil at a high velocity is the first step in the erosion process. Raindrops shatter the soil granules and clods, reducing them to smaller particles and thereby reducing the infiltration capacity of soil. The force of the raindrops also carries the splashed soil, resulting in movement of soil downslope.

When the rate of rainfall exceeds the rate of infiltration, depressions on the surface fill and overflow, causing runoff. Runoff water breaks suspended soil particles into smaller sizes, which helps to keep them in suspension.

3.2.1.1 Factors affecting surface erosion -

Factors which have been considered the most significant in affecting erosion of topsoil consist of:

1. Rainfall characteristics,

2. Soil properties,

3. Slope factors,

4. Land cover conditions, and

5. Conservation practices.

Rainfall characteristics define the ability of the rain to splash and erode soil. Rainfall energy is determined by drop size, velocity, and intensity characteristics of rainfall.

Soil properties affect both detachment and transport processes. Detachment is related to soil stability, basically the size, shape, composition, and strength of soil aggregates and clods. Transport is influenced by permeability of soil to water, which determines infiltration capabilities and drainage characteristics; by porosity, which affects storage and movement of water; and by soil surface roughness, which creates a potential for temporary detention of water.

Slope factors define the transport portion of the erosion process. Slope gradient and slope length influence the flow and velocity of runoff.

Land cover conditions affect detachment and transportation of soil. Land cover by plants and their residues provides protection from impact of raindrops. Vegetation protects the ground from excessive evaporation, keeps the soil moist, and thus makes the soil aggregates less susceptible to detachment. In addition, residues and stems of plants furnish resistance to overland flow, slowing down runoff velocity and reducing erosion.

Conservation practices concern modification of the soil factor or the slope factor, or both, as they affect the erosion sequence. Practices for erosion control are designed to do one or more of the following: (a) dissipate raindrop impact forces; (b) reduce quantity of runoff; (c) reduce runoff velocity; and (d) manipulate soils to enhance the resistance to erosion.

3.2.1.2 Effect of man's activities on surface erosion -

Man alters surface erosion primarily by changing cover and altering the hydraulic system through which the water and sediment are transported.

Activities which impact surface erosion can be categorized into four classes: cropping practices, silvicultural activities, mining activities, and construction activities. Depending on the initial status of land and the nature of activity, a wide range of impact can be expected. Table 3-1 lists some reported values of the magnitude of the impact.

Surface erosion from croplands - Cropping practices change the soil cover so that it favors one type of plant and discourages the growth of others. The practices expose the soil and leave it loose and liable to erosion.

Table 3-1. SOME REPORTED QUANTITATIVE EFFECTS OF MAN'S ACTIVITIES ON SURFACE EROSION

Initial status	Type of disturbance	Magnitude of impact by the specific disturbance[a]	Reference
Forestland	Planting row crops	100-1,000	Brown (2)
Grassland	Planting row crops	20-100	Brown (2)
Forestland	Building logging roads	220	Megahan (3)
Forestland	Woodcutting and skidding	1.6	Megahan (3)
Forestland	Fire	7-1,500	Ralston and Hatchell (4)
Forestland	Mining	1,000	Collier et al. (5)
Row crop	Construction	10	USDA/SCS (6)
Pastureland	Construction	200	USDA/SCS (6)
Forestland	Construction	2,000	USDA/SCS (6)

---

a/ Relative magnitude of surface erosion from disturbed surface, assuming "1" for the initial status. The first row of the table, for example, indicates that transforming a forestland into row crops will increase surface erosion 100 to 1,000 times.

Soil erosion can be affected by cropping practices such as tillage, irrigation, planting, fertilization, and residue disposition.

Tillage detaches soil and promotes oxidation of organic matter in soils. These processes decrease aggregation and reduce the infiltration capacity. Plowing creates a plow pan. Agricultural machinery compresses the soil, reducing large-pore space and, consequently, its infiltration capacity. All this results in higher runoff and erosion rates.

Crop planting varies in its effect on erosion, depending on the species, the stand density, the distance between the rows, and the direction of the rows with respect to the slope. The denser and the more nearly on the contour the planting is made, the less erosion will result.

Fertilization helps to ensure stands, causes faster and heavier growth, and is consequently a help in protecting the soil and in creating beneficial residues. Manure can serve both as a fertilizer and a ground cover.

Crop residues help to protect soil from detachment by rainfall and runoff. They also contribute to making up organic matter in soils and therefore increase soil stability against water erosion.

Surface erosion from forestlands - Forestland generally can be characterized by: (a) a vegetative canopy above the ground surface; (b) a layer of decayed and undecayed plant remains on the surface; and (c) a system of living and dead roots within the soil body. These conditions insulate the soil against the impact of rain, obstruct overland flow, and retard movement of soil by water action. These conditions reduce erosion and sediment production to a minimum.

Major causes of erosion on forestlands include:

1. Damage to cover from cutting, logging, and reforestation activities, and construction of roads and fire lanes.

2. Damage to cover because of fire, grazing, and recreational activity.

3. Damage on land reverting to forest cover from other land use, such as strip mines, and on which adequate cover conditions have not developed.

Surface erosion from pasturelands - The dense cover of grasses, legumes, and other low growing plants is generally effective in protecting the soil from erosion by rainfall and runoff. Consequently, the amount of erosion from a well-managed pasture is small.

Overgrazing is the major cause of accelerated erosion on pasturelands. The grazing animals may eat the forage down to the ground, lessening the effectiveness of plants in intercepting the raindrops. Open spots on pasturelands can erode as rapidly as cultivated fields.

Surface erosion from construction sites and mining sites - Construction and mining activities involve extensive earth-moving operations. In these diverse earth-moving activities, the natural protective ground cover is disturbed; compacted soils are dislodged and redistributed; highly erosive soils from the deeper horizons are exposed to the elements; shallower, smoother terrain is recontoured to steeper slopes; and runoff is often increased and accelerated.

Sediment production from construction sites differs from that caused by other types of nonpoint sources in that it is generally of limited duration. Agricultural operations continue to produce sediment-containing runoff year after year, while intensive sediment yields from a construction project typically last from a few weeks to a few years, during which time the areas of exposed soils may be well stabilized by vegetation, chemical application, or other control measures, either permanent or temporary.

3.2.1.3 Sediment delivery ratio -

Sediment loadings to surface waters are dependent on erosion processes at the sediment sources and on the transport of eroded material to the receptor water. Only a part of the material eroded from upland areas in a watershed is carried to streams or lakes. Varying proportions of the eroded materials are deposited at the base of slopes, in swales, or on flood plains.

The portion of sediment delivered from the erosion source to the receptor water is expressed by the delivery ratio.

Factors affecting sediment delivery ratio - Many factors influence the sediment delivery ratio. Variations in delivery ratio may be dependent on some or all of the following factors and others not identified. The reader is referred to References 7 and 8 for more detailed discussion of the subject.

> Proximity of sediment sources to the receptor water--e.g., channel-type erosion produces sediment that is immediately available to the stream transport system, and therefore has a high delivery ratio. Materials derived from surface erosion, however, often move only short distances and may lodge in areas remote from the stream, and therefore have a low delivery ratio.
>
> Size and density of sediment sources--when the amount of sediment available for transport exceeds the capability of the runoff transport system, deposition occurs and the sediment delivery ratio is decreased.

Characteristics of transport system--runoff resulting from rainfall and snowmelt is the chief agent for transporting eroded material. The ability to transport sediment is dependent on the velocity and volume of water discharge.

Texture of eroded material--in general, delivery ratio is higher for silt or clay soils than for coarse textured soils.

Availability of deposition areas--deposition of eroded material mostly occurs at the foot of upland slopes, along the edges of valleys and in valley flats.

Relief and length of watershed slopes--the relief ratio of a watershed has been found to be a significant factor influencing the sediment-delivery ratio. The relief ratio is defined as the ratio between the relief of watershed between the minimum and maximum elevation, and the maximum length of watershed.

3.2.2 Sediment Loading Function for Surface Erosion

Sediment loading is defined in this handbook as the quantity of soil material that is eroded and transported into the watercourse. Sediment loading is dependent on (a) on-site erosion, and (b) delivery, or the ability of runoff to carry the eroded material into the receptor water.

The sediment loading function is based on concepts of the mechanisms of gross erosion and sediment delivery. The Universal Soil Loss Equation[9/] (USLE) is chosen to predict the on-site surface (including sheet and rill) erosion, for the following reasons:

1. This equation is applicable to a wide variety of land uses and climatic conditions.

2. It predicts erosion rates by storm event and season, in addition to annual averages.

3. An extensive nationwide collection of data has been made for factors included in the equation.

The sediment loading function has the form:

$$Y(S)_E = \sum_{i=1}^{n} \left[A_i \cdot (R \cdot K \cdot L \cdot S \cdot C \cdot P \cdot S_d)_i\right] \qquad (3\text{-}1)$$

where $Y(S)_E$ = sediment loading from surface erosion, tons/year

n = number of subareas in the area

Source areal factor:

A_i = acreage of subarea i, acres

Source characteristic factors:

R = the rainfall factor, expressing the erosion potential of average annual rainfall in the locality, is a summation of the individual storm products of the kinetic energy of rainfall, in hundreds of foot-tons per acre, and the maximum 30-min rainfall intensity, in inches per hour, for all significant storms, on an average annual basis

K = the soil-erodibility factor, commonly expressed in tons per acre per R unit

L = the slope-length factor, dimensionless ratio

S = the slope-steepness factor, dimensionless ratio

C = the cover factor, dimensionless ratio

P = the erosion control practice factor, dimensionless ratio

S_d = the sediment delivery ratio, dimensionless

The R factor in the above equation can be expressed in metric units [(hundreds of meter-metric tons/ha-cm) times (maximum 30-min intensity, cm/hr)] by multiplying the English R values by 1.735. The factor for direct conversion of K to metric-tons per hectare per metric R unit is 1.292.[10/]

Equation (3-1) can be used to predict sediment loading resulting from sheet and rill erosion from noncroplands as well as croplands. Parameter values for silviculture, construction, and mining are less well documented than for agriculture, however. The user will thus find it relatively easy to use Eq. (3-1) for agriculture, and substantially more difficult for other sources. It does not predict sediment contributions from gully erosion, streambank erosion, or mass soil movement.

In Sections 3.2.3 and 3.2.4 below, procedures and an example will be presented for estimating sediment loadings based on the above described loading function. Section 3.2.5 presents data and data sources of source characteristic factors. Methodology for predicting minimum and maximum erosion rates is presented in Section 3.2.6. Section 3.2.7 presents data sources for source areal factors.

3.2.3 Procedure for Use of the Sediment Loading Function

The following procedure is to be used to calculate sediment loading from a designated area based on the loading function in Eq. (3-1). The terminology applies to agricultural lands, but the procedure is applicable to other non-point sources. This procedure is shown as a flow diagram in Figure 3-1.

Estimation of surface erosion should be made for each land-use type. For a land-use type, if 90% or more of the area is made up of one soil type, one may calculate soil loss for the land use based on that soil type. If there is less than 90% of one soil type, one should calculate soil loss for each soil type that makes up at least 10% of the land use, and then obtain a weighted average for the entire land-use area.[11]

Obtain basic land data -

Total area, and land use acres in the area: cropland, pastureland, and woodland, etc.

Soil characteristic information including soil name, soil texture, etc., for each land use.

Information about canopy and ground cover condition for each land use.

Topographic information, such as slope gradient and slope length of the land.

Information about the type and extent of conservation practices.

Determine factor values -

Determine R: Use the appropriate isoerodent map (see Figure 3-2 and 3-3), or procedures described in the Section 3.2.5.1 for the western United States.

Obtain K: Obtain the K values of the named soils from published lists of SCS, or determine K values on nomographs (Figures B-1 and B-2 in Appendix B) from soil properties.

Determine LS: Refer to Figures 3-7 or 3-8 for uniform slopes, or Figure 3-9 for irregular slopes.

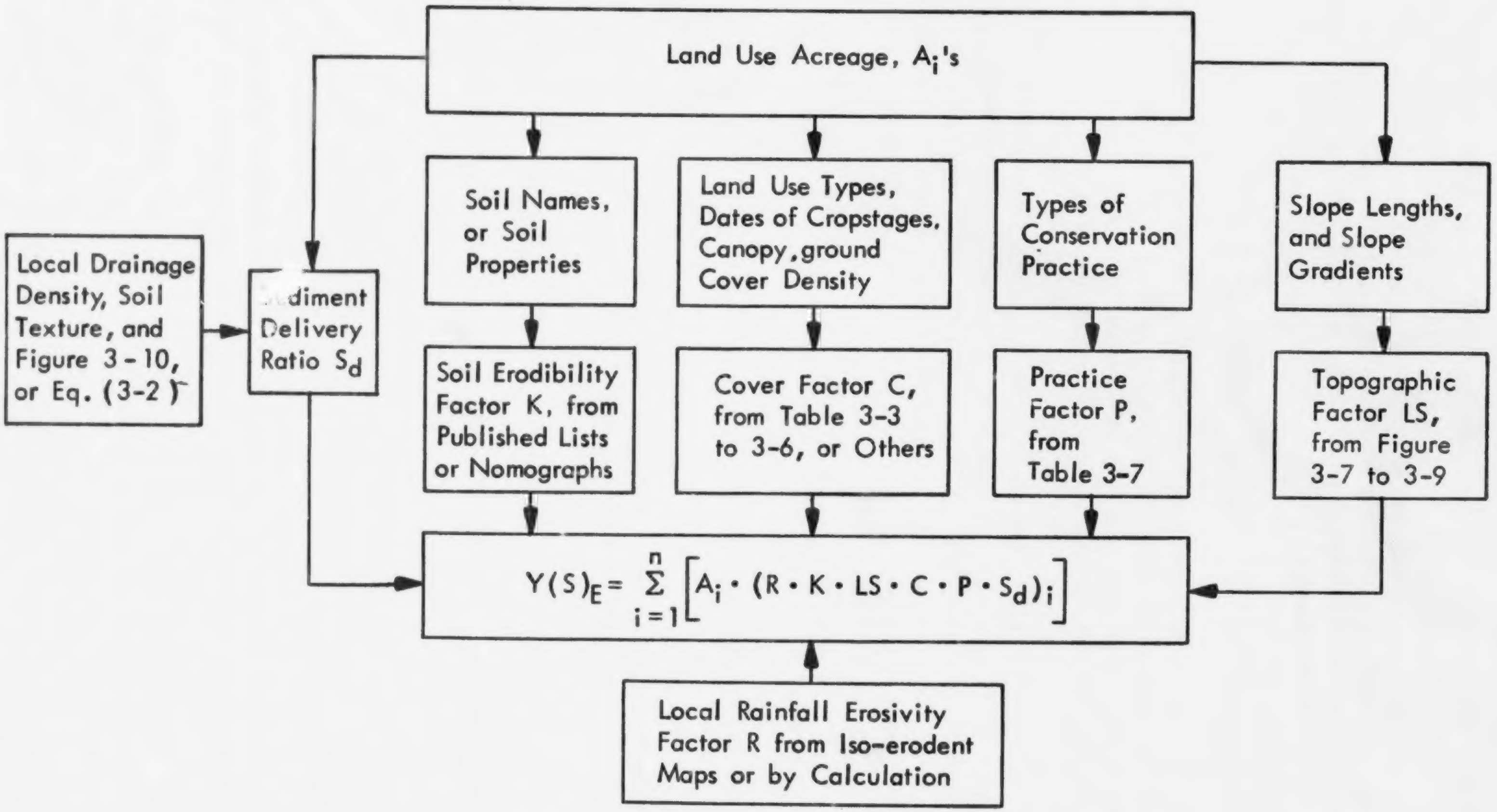
Land Use Acreage, A_i's
Local Drainage Density, Soil Texture, and Figure 3-10, or Eq. (3-2)
Sediment Delivery Ratio S_d
Soil Names, or Soil Properties
Land Use Types, Dates of Cropstages, Canopy, ground Cover Density
Types of Conservation Practice
Slope Lengths, and Slope Gradients
Soil Erodibility Factor K, from Published Lists or Nomographs
Cover Factor C, from Table 3-3 to 3-6, or Others
Practice Factor P, from Table 3-7
Topographic Factor LS, from Figure 3-7 to 3-9
$Y(S)_E = \sum_{i=1}^{n} \left[A_i \cdot (R \cdot K \cdot LS \cdot C \cdot P \cdot S_d)_i \right]$
Local Rainfall Erosivity Factor R from Iso-erodent Maps or by Calculation

Figure 3-1. Flow diagram for calculating sediment loading from surface erosion

Obtain C: Refer to the appropriate table for the crop or ground cover condition for C value in Section 3.2.5.4.

Obtain P: Refer to Table 3-7.

Determine sediment delivery ratio, S_d: Obtain from local sources or from Figure 3-10 by using drainage density and soil texture for homogeneous watersheds.

Calculations -

Multiply R, K. LS, C, and P, and S_d to obtain sediment loadings for cropland, pasture, and woodland in annual yields per unit area of source.

Multiply loading rates by source sizes (total hectares or acres) for cropland, pastureland, and woodland to obtain total loading per source.

Sum source loadings calculated in the item above to obtain total loading from land uses (total loading in the watershed will require summation of other sources within the watershed).

3.2.4 Example of Assessing Sediment Loading from Surface Erosion

Assume a watershed area of 830 acres in Parke County, Indiana (west central). Compute sediment loading from the watershed from sheet and rill erosion in terms of average daily loading, maximum daily loading during a 30-consecutive-day period, and minimum during a 30-consecutive-day period.

Basic information -

Land use types:

- Cropland
- Pasture
- Woodland

Delivery ratio: 60%

Land information:

Cropland - 180 acres

- Continuous corn
- Conventional tillage, average yield ~ 40 to 45 bu
- Cornstalks are left after harvest
- Contour strip-cropped

Soil - Fayette silt loam
Slope - 6%
Slope length - 250 ft

Pasture - 220 acres

No appreciable canopy
Cover at surface - grass and grasslike plants
Percent of surface or ground cover - 80%
Soil - Fayette silt loam
Slope - 6%
Slope length - 200 ft

Woodland - 430 acres

Medium stocked
Percent of area covered by tree canopy - 50%
Percent of area covered by litter - 80%
Undergrowth - managed
Soil - Bates silt loam
Slope - 12%
Slope length - 150 ft

Maximum and minimum rates - The ratios between 30-day maximum and average daily rates, and 30-day minimum and average daily rates for continuous corn, pasture, and woodland for this area are evaluated in Section 3.2.6. They are:

Continuous corn: Ratio--30-day maximum/average daily = 3.2
Ratio--30-day minimum/average daily = 0.25

Pasture and woodland: Ratio--30-day maximum/average daily = 2.5
Ratio--30-day minimum/average daily = 0.25

Calculations of loading per acre -

Cropland:

R = 200 (Figure 3-2)

K = 0.37 (USDA-SCS)

LS = 1.08 (Figure 3-8)

C = 0.49 (Section 3.2.5.4)

$P = 0.25$ (Table 3-7)

$S_d = 0.60$

Calculate average annual loading per acre.

$$\begin{aligned} Y(S)_{\text{annual}} &= 200 \times 0.37 \times 1.08 \times 0.49 \times 0.25 \times 0.6 \\ &= 5.87 \text{ tons/acre/year} \end{aligned}$$

Calculate average daily loading per acre.

$$\begin{aligned} Y(S)_{\text{avg. daily}} &= 5.87 \text{ tons/acre/year} \div 365 \text{ days} \\ &= 0.016 \text{ tons/acre/day} = 32 \text{ lb/acre/day} \end{aligned}$$

Calculate maximum loading per acre during a 30-consecutive-day period.

$$\begin{aligned} Y(S)_{\text{30-day max}} &= 0.016 \text{ tons/acre/day} \times 3.2 \\ &= 0.052 \text{ tons/acre/day} = 104 \text{ lb/acre/day} \end{aligned}$$

Calculate minimum loading per acre during a 30-consecutive-day period.

$$\begin{aligned} Y(S)_{\text{30-day min}} &= 0.016 \text{ tons/acre/day} \times 0.25 \\ &= 0.004 \text{ tons/acre/day} = 8 \text{ lb/acre/day} \end{aligned}$$

Pasture:

$R = 200$

$K = 0.37$

$LS = 0.95$

$C = 0.013$ (Table 3-4)

$P = 1.0$

$S_d = 0.60$

$$\begin{aligned} Y(S)_{\text{annual}} &= 200 \times 0.37 \times 0.95 \times 0.013 \times 1.0 \times 0.6 \\ &= 0.548 \text{ tons/acre/year} = 1{,}100 \text{ lb/acre/year} \end{aligned}$$

$$\begin{aligned} Y(S)_{\text{avg. daily}} &= 0.548 \text{ tons/acre/year} \div 365 \text{ days} \\ &= 0.0015 \text{ tons/acre/day} = 3 \text{ lb/acre/day} \end{aligned}$$

$Y(S)_{\text{30-day max}}$ = 0.0015 tons/acre/day x 2.5
= 0.0038 tons/acre/day = 7.6 lb/acre/day

$Y(S)_{\text{30-day min}}$ = 0.0015 tons/acre/day x 0.25
= 0.0004 tons/acre/day = 0.8 lb/acre/day

Woodland:

R = 200

K = 0.32

LS = 2.75

C = 0.003 (Table 3-5)

P = 1.0

S_d = 0.60

$Y(S)_{\text{annual}}$ = 200 x 0.32 x 2.75 x 0.003 x 1.0 x 0.60
= 0.3168 tons/acre/year

$Y(S)_{\text{avg. daily}}$ = 0.3168 tons/acre/year ÷ 365 days
= 0.0009 tons/acre/day = 1.8 lb/acre/day

$Y(S)_{\text{30-day max}}$ = 0.0009 tons/acre/day x 2.5
= 0.0022 tons/acre/day = 4.4 lb/acre/day

$Y(S)_{\text{30-day min}}$ = 0.0009 tons/acre/day x 0.25
= 0.0002 tons/acre/day = 0.4 lb/acre/day

Calculations of gross loading -

Average daily:

Cropland - 180 acres x 0.016 tons/acre/day = 2.88 tons/day

Pasture - 220 acres x 0.0015 tons/acre/day = 0.33 tons/day

Woodland - 430 acres x 0.0009 tons/acre/day = 0.39 tons/day

Total $Y(S)_{\text{avg. total}}$ = 3.60 tons/day

30-day maximum:

Cropland - 180 acres x 0.052 tons/acre/day = 9.36 tons/day

Pasture - 220 acres x 0.0038 tons/acre/day = 0.84 tons/day

Woodland - 430 acres x 0.0022 tons/acre/day = 0.95 tons/day

Total $Y(S)_{30\text{-max total}}$ = 11.15 tons/day

30-day minimum:

Cropland - 180 acres x 0.004 tons/acre/day = 0.72 tons/day

Pasture - 220 acres x 0.0004 tons/acre/day = 0.09 tons/day

Woodland - 430 acres x 0.0022 tons/acre/day = 0.09 tons/day

Total $Y(S)_{30\text{-day min total}}$ = 0.90 tons/day

3.2.5 Determination of Source Characteristic Factors

3.2.5.1 The rainfall factor (R) -

R is a factor expressing the erosion potential of precipitation in a locality. It is also called index of erosivity, erosion index, etc. It is the summation of the individual storm products of the kinetic energy of rainfall (denoted by E), and the maximum 30-min rainfall intensity (denoted by I) for all significant storms within the period under consideration. The product EI reflects the combined potential of raindrop impact and runoff turbulence to transport dislodged soil particles from the site.[9]

Values of average annual rainfall-erosivity index, R, are shown in Figure 3-2 for the continental U.S. and Figure 3-3 for islands of Hawaii. On these maps, the lines joining points with the same erosion index value are called isoerodents. Points lying between the indicated isoerodents may be approximated by linear interpolation.

Interpolation for values of R factors in the mountainous areas, particularly those west of the 104th meridian may not be appropriate because of the sporadic rainfall pattern. Values of the erosion index at specific areas can be computed from local recording rain gage records with the help of a rainfall-energy table and the computation procedure presented by Wischmeier and Smith.[12]

ARS recently recommended that 350 be the maximum used in the Gulf and southeastern states, shown in Figure 3-2, until further research can validate values higher than 350.

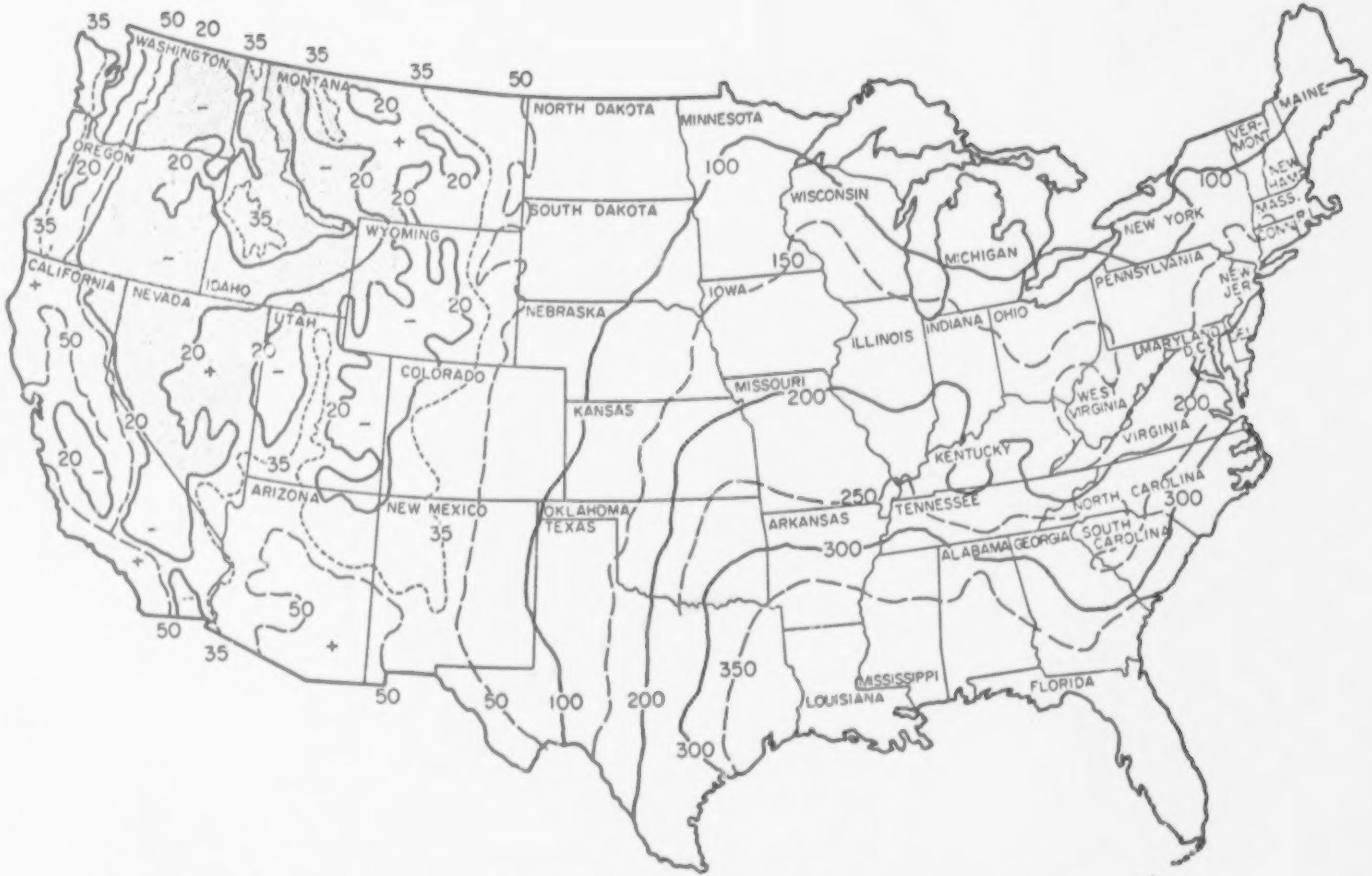
35
50
20
35
35
35
50
WASHINGTON
MONTANA
NORTH DAKOTA
MINNESOTA
MAINE
VER-MONT
NEW HAMP.
MASS.
CONN.
R.I.
OREGON
IDAHO
WYOMING
SOUTH DAKOTA
WISCONSIN
MICHIGAN
NEW YORK
PENNSYLVANIA
NEW JER.
CALIFORNIA
NEVADA
UTAH
COLORADO
NEBRASKA
IOWA
ILLINOIS
INDIANA
OHIO
MARYLAND
D.C.
DEL.
WEST VIRGINIA
VIRGINIA
KANSAS
MISSOURI
KENTUCKY
ARIZONA
NEW MEXICO
OKLAHOMA
TEXAS
ARKANSAS
TENNESSEE
NORTH CAROLINA
SOUTH CAROLINA
ALABAMA
GEORGIA
MISSISSIPPI
LOUISIANA
FLORIDA
20
100
150
200
250
300
350
50
100
200
300

Figure 3-2. Average annual values of the rainfall-erosivity factor, R[a]

---

[a] Source: "Control of Water Pollution from Cropland, Volume I - A Manual for Guideline Development," Agricultural Research Service, USDA (Report No. ARS-H-5-1), and Office of Research and Development, EPA (Report No. EPA-600/2-75-026a), Washington, D.C., November 1975.

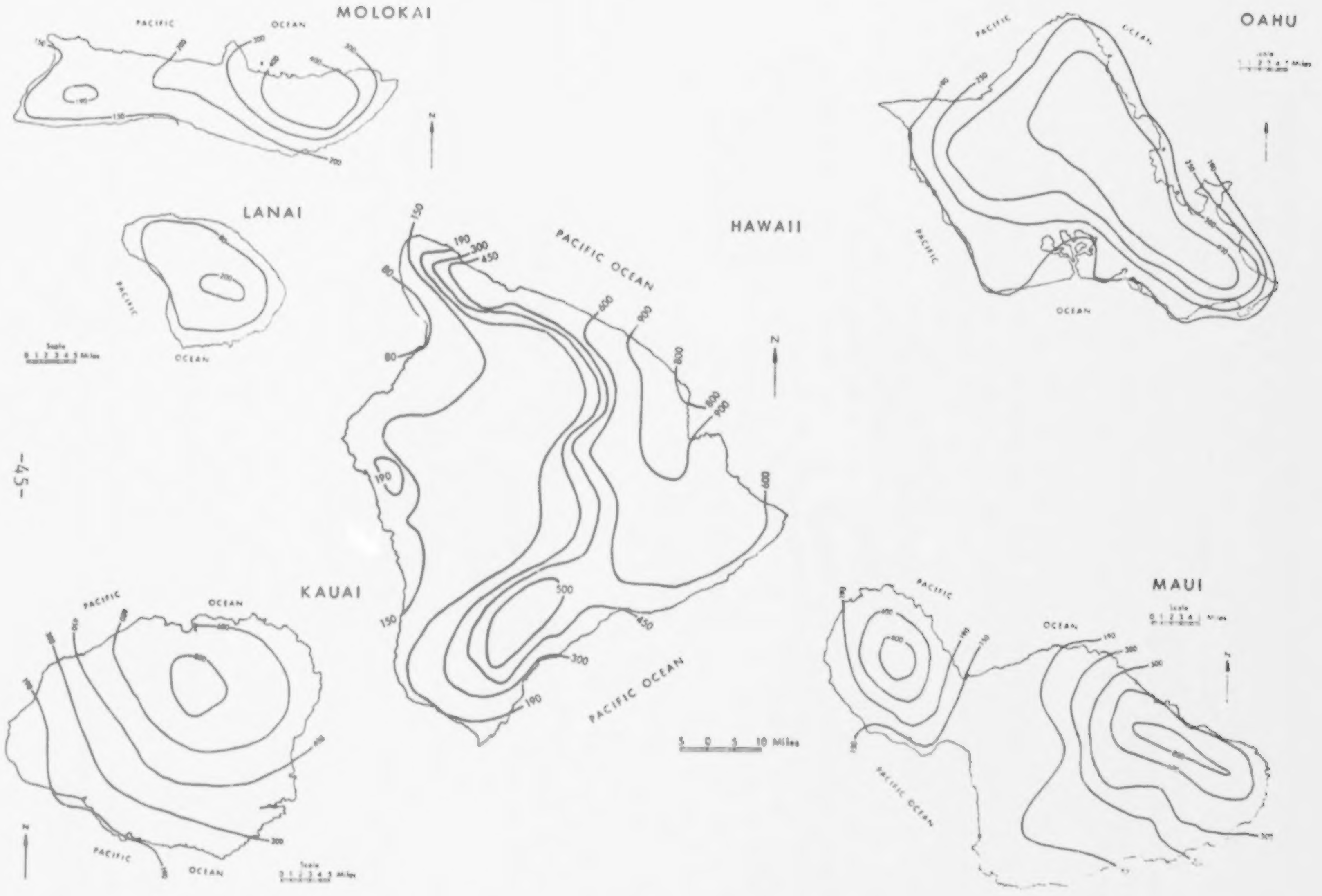
MOLOKAI
PACIFIC
OCEAN
LANAI
PACIFIC
OCEAN
HAWAII
PACIFIC OCEAN
PACIFIC OCEAN
80
150
190
300
450
500
600
800
900
5 0 5 10 Miles
OAHU
PACIFIC
OCEAN
KAUAI
PACIFIC
OCEAN
MAUI
PACIFIC
OCEAN
PACIFIC OCEAN
Scale
0 1 2 3 4 5 Miles
N

Figure 3-3. Mean annual values of erosion index (in English units) for Hawaii11/

In the northwestern United States, runoff from snowmelt contributes significantly to surface erosion. The annual index of R for some portions of this region is the combined effect of rainfall and snowmelt designated by R_r and R_s, respectively. The snowmelt factor (R_s) is important in Areas A-1, B-1, and C on Figure 3-4 (also refer to Table 3-2). The map values in the shaded region of the Northwest (see Figure 3-2) represent values for the rainfall effect (R_r) only, and must be added with appropriate R_s values to account for the effect of runoff from thaw and snowmelt.

Interim procedures for calculating annual R values, which include both R_r and R_s, for the northwestern U.S. are described in Conservation Agronomy Technical Note No. 32, USDA/SCS, Portland, Oregon, September 1974,[13/] and are briefly presented below.

Annual R_r factor: The annual R_r factor is obtained by using as base the 2-year, 6-hr rainfall (2-6 rainfall). Relationships between R_r and 2-6 rainfall vary to conform to specific local climatic characteristics. These relationships are designated as Type I, Type IA, and Type II, and are shown in Figure 3-5. Specific areas applicable to these curves are shown in Figure 3-6. Type I curve is for the central valley and coastal mountains and valleys of southern California. Type IA curve applies to the coastal side of the Cascades in Oregon and Washington, the coastal side of the Sierra Nevada Mountains in northern California, and the coastal regions of Alaska. Type II curve applies to the remainder of the region. For 2-6 rainfall data, refer to Technical Paper No. 40, U.S. Department of Commerce, Weather Bureau, Washington, D.C., May 1961, or other suitable rainfall frequency analysis reports.

Annual R_s factor: To obtain the annual R_s factor for a given location, obtain the average annual total precipitation by snowfall (in inches of water depth) and multiply it by the constant 1.5 to give annaul R_s.

Sources of snowfall data: The 1941 Yearbook of Agriculture, USDA, Washington, D.C.; "Climates of the States," Water Information Center, Inc., Port Washington, New York, 1974; data resulting from the Western Federal-State-Private Cooperative Snow Surveys, coordinated by SCS/USDA, Portland, Oregon; or other equally suitable precipitation records.

Data on snow density is necessary to convert depth of snow to depth of meltwater. Snow at the time of fall may have a density as low as 0.01 and as high as 0.15 g/ml. The average snow density for the United States is taken to be 0.10.[14/] If snowfall is recorded as inches of precipitation, no conversion is required.

Annual R factor: The annual R factor for the western United States is the summation of effect of rainfall, R_r, and snowmelt, R_s. Where R_s is not significant, values of R and R_r are the same.

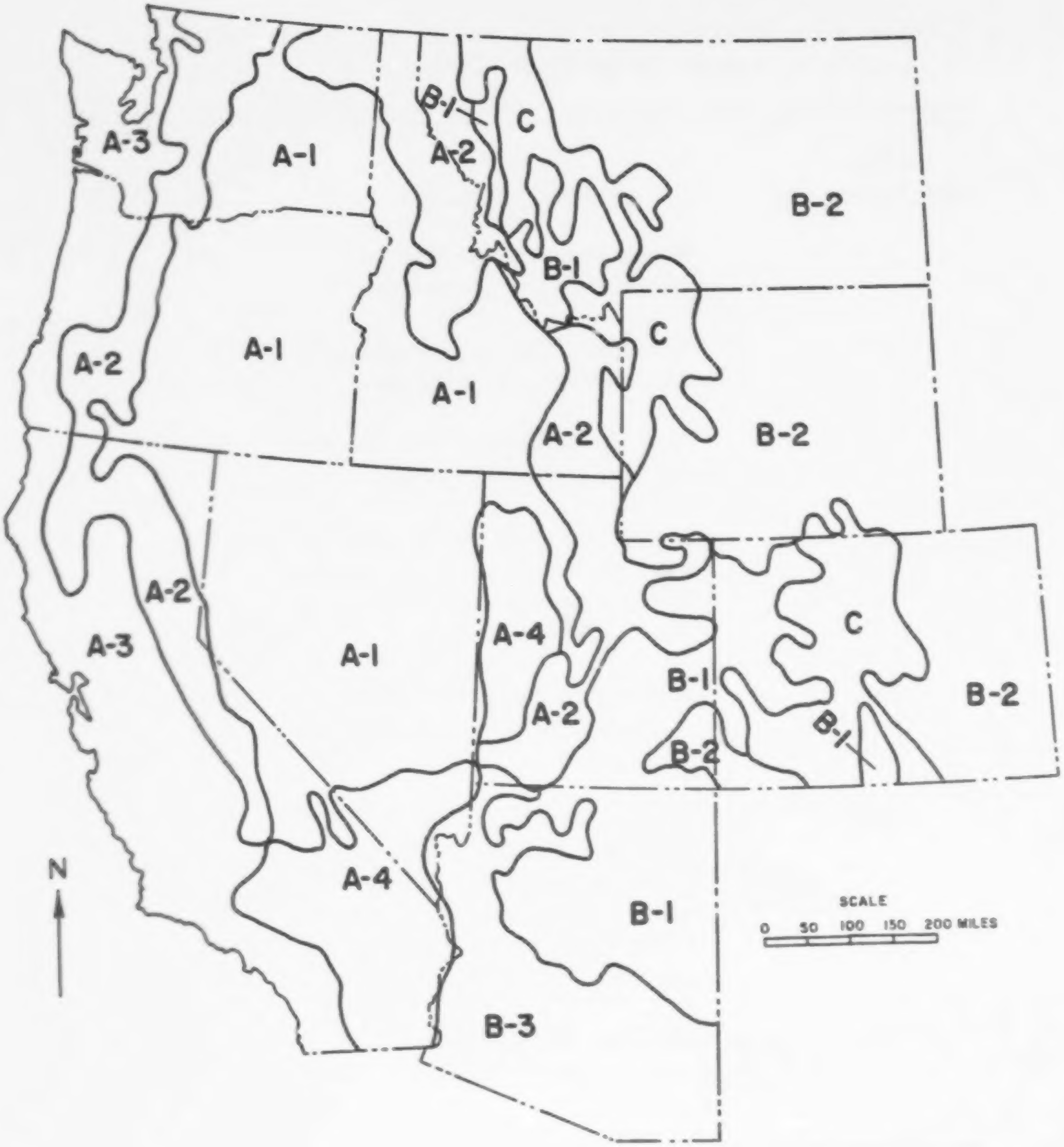
A-3
A-1
B-1
A-2
C
B-2
B-1
A-2
A-1
C
A-1
A-2
B-2
A-3
A-2
A-1
A-4
C
B-1
A-2
B-2
B-2
B-1
A-4
B-1
B-3
N
SCALE
0 50 100 150 200 MILES

Figure 3-4. Soil moisture - soil temperature regimes of the western United States[13]

Table 3-2. APPLICABILITY OF R_r AND R_s FACTORS IN THE AREAS WEST OF THE ROCKY MOUNTAINS[13]

Areas (see Figure 3-3)	Typical locations	R_r	R_s
A-1	Washington, Idaho, Nevada, California, western Utah	X[a]	X
A-2	Cascades, Sierra, Tetons of Idaho, Wasatch Mountains	X	-[b]
A-3	West of Cascades, San Joaquin Valley, west of Sierras	X	-
A-4	Areas of southern California, east of Santa Annas, southern Nevada, intermountain Nevada, Salt Lake area, Utah	X	-
B-1	Western Montana, Colorado, eastern Utah, high elevations of Arizona	X	X
B-2	Great plains area of eastern Montana, Wyoming, Colorado (includes gently sloping mesas and upland at lower elevations of Monticello, Utah area)	X	-
C	Rainfall during summer is high; high elevations	X	X

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[a] X needed.

[b] - Not needed.

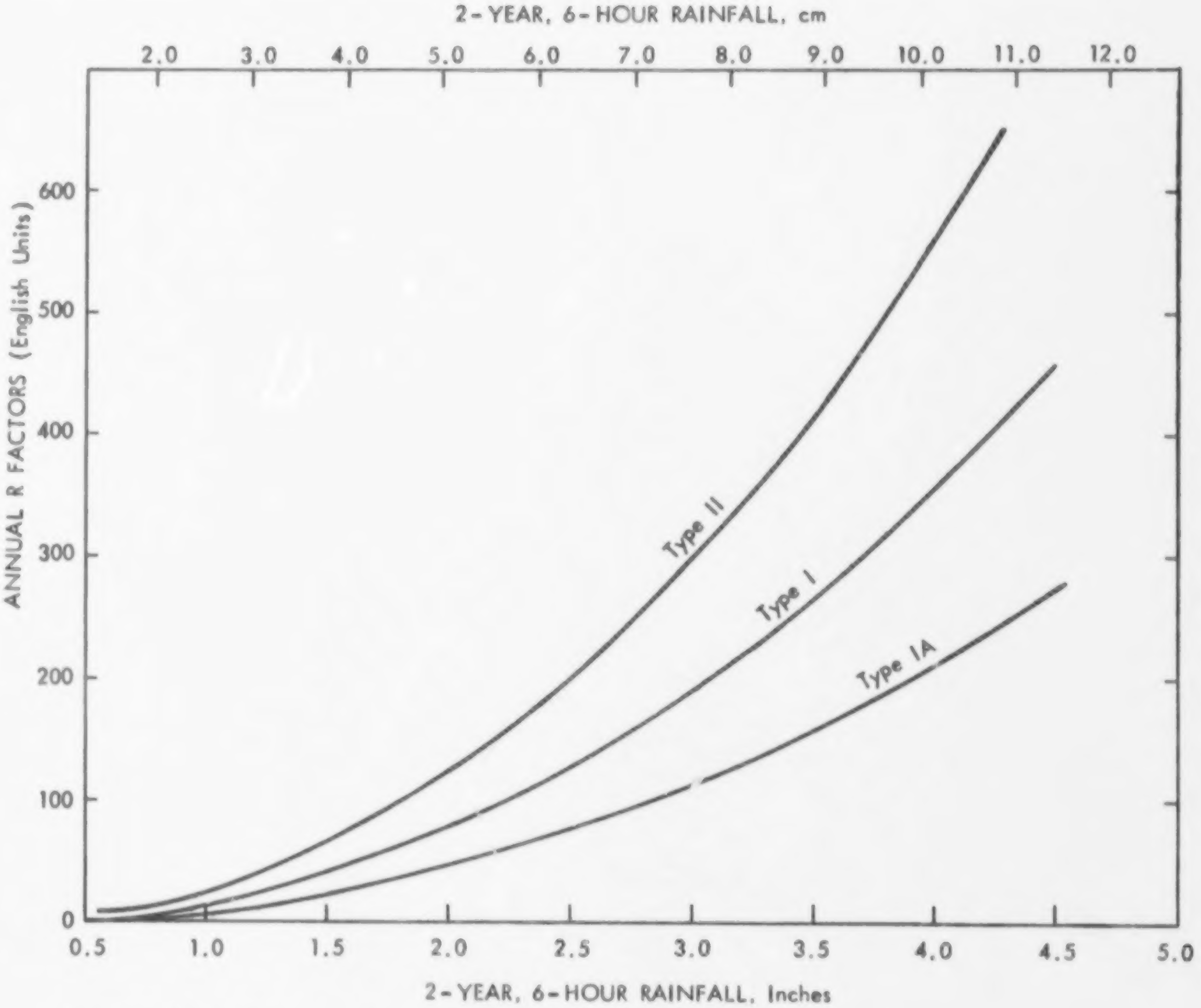

Figure 3-5. Relationships between annual average rainfall erosivity index and the 2-year, 6-hr rainfall depth for three rainfall types in the western United States[13]

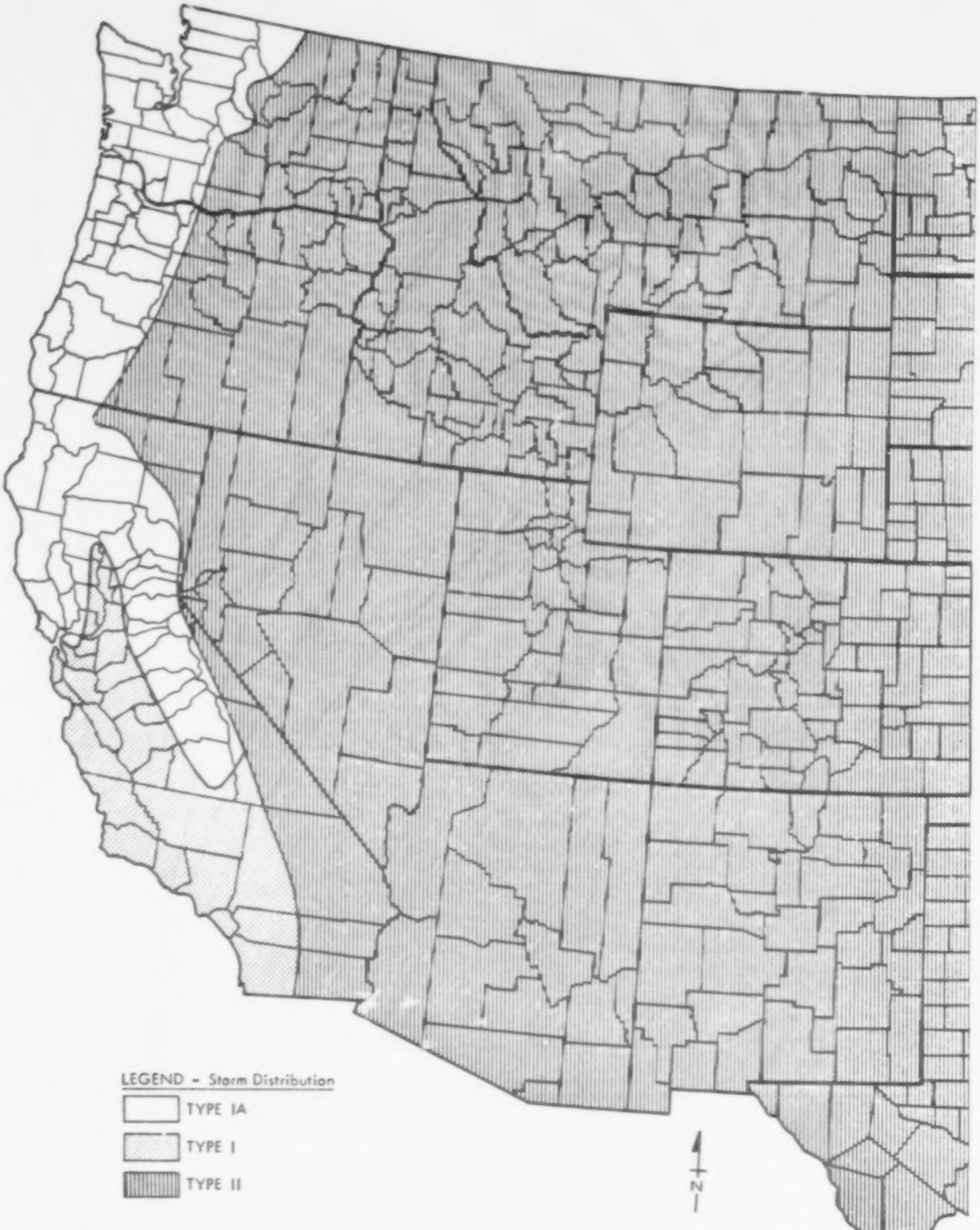
LEGEND - Storm Distribution
TYPE IA
TYPE I
TYPE II
N

Figure 3-6. Storm distribution regions in the western United States[13/]

Monthly distribution of R factor - The monthly distribution of the erosion index for the 37 states east of the Rocky Mountains has been reported in USDA-ARS Agriculture Handbook No. 282.[9] The erosion index distribution curves are reproduced and shown in Appendix A. Average monthly erosion index values are expressed as percentages of average annual values and plotted cumulatively against time.

The monthly distribution of erosion index for the islands of Hawaii also has been developed.[11] These curves are shown in Appendix A.

For the areas west of the Rockies in the continental United States, the monthly distribution of erosion index R is the summation of R_r and R_s. Where R_s values are not needed, the R and R_r curves are the same.

As of June 1974, the monthly R distribution curves for portions of the area had been made available.[13] The reader should contact the state Soil Conservation Service for such information. Procedures suggested by SCS for computing and plotting monthly R distribution curves for the western United States are described in Appendix A.

3.2.5.2 The soil-erodibility factor (K) -

K factor is a quantitative measure of the rate at which a soil will erode, expressed as the soil loss (tons) per acre per unit of R, for a plot with 9% slope, 72.6 ft long, under continuous cultivated fallow.

K factors for topsoils, as well as subsoils, for most soil series have been developed. Values of K for soils studied thus far vary from 0.12 to 0.70 tons/acre/unit R.

The K values for named soils at different locations of the nation can be obtained from the regional or state offices of the Soil Conservation Service.

K values of soils can be predicted from soil properties. In Appendix B of this handbook, two nomographs are presented from which K values may be determined for topsoils and subsoils when the governing soil properties are known.

3.2.5.3 The topographic factor (LS) -

Soil loss is affected by both length (L) and steepness of slope (S). These factors affect the capability of runoff to detach and transport soil material.

The slope length factor is the ratio of soil loss from a specific length of slope to that length (72.6 ft) specified for the K factor in the equation. Slope length is defined as the distance from the point of origin of overland flow to either of the following, whichever is limiting, for the major part of the area under consideration: the point where the slope decreases to the extent that deposition begins; or the point where runoff enters a well-defined channel that may be part of a drainage network, or a constructed channel that may be part of a drainage network, or a constructed channel such as a terrace or diversion. Slope length can be determined accurately by on-site inspection of a field, or by measurements from aerial photographs, or topographic maps. When the land is terraced, the terrace spacing should be used. All slope lengths are compared to a slope length of 72.6 ft, which has a factor value of 1.

The slope gradient or percent slope factor is the ratio of soil loss from a specific percent slope to that slope (9%) specified for the K value in the ULSE. A 9% slope has a factor value of 1. Slope data may be obtained from topographic maps, engineering or land level surveys, and other sources. A widely used method is to estimate slope from soil survey maps in which the soils have been mapped by slope range.

The slope length (L) and slope gradient (S) are combined in the USLE into a single dimensionless topographic factor, LS, which can be evaluated using a slope-effect chart.

Slope-effect charts for uniform slopes - The slope-effect chart in Figure 3-7 is designed for the following areas shown in Figure 3-4: A-1 in Washington, Oregon, and Idaho; and all of A-3.[13]

For the remainder of the U.S., the slope-effect chart, Figure 3-8, is to be used.[13]

Slope-effect charts in Figure 3-7 and 3-8 can be used when uniform slopes are assumed. The following steps are to be used for obtaining LS values from these charts:

1. Enter the chart on the horizontal axis with the appropriate value of slope length.

2. Follow the vertical line for that slope length to where it intersects the curve for the appropriate percent slope.

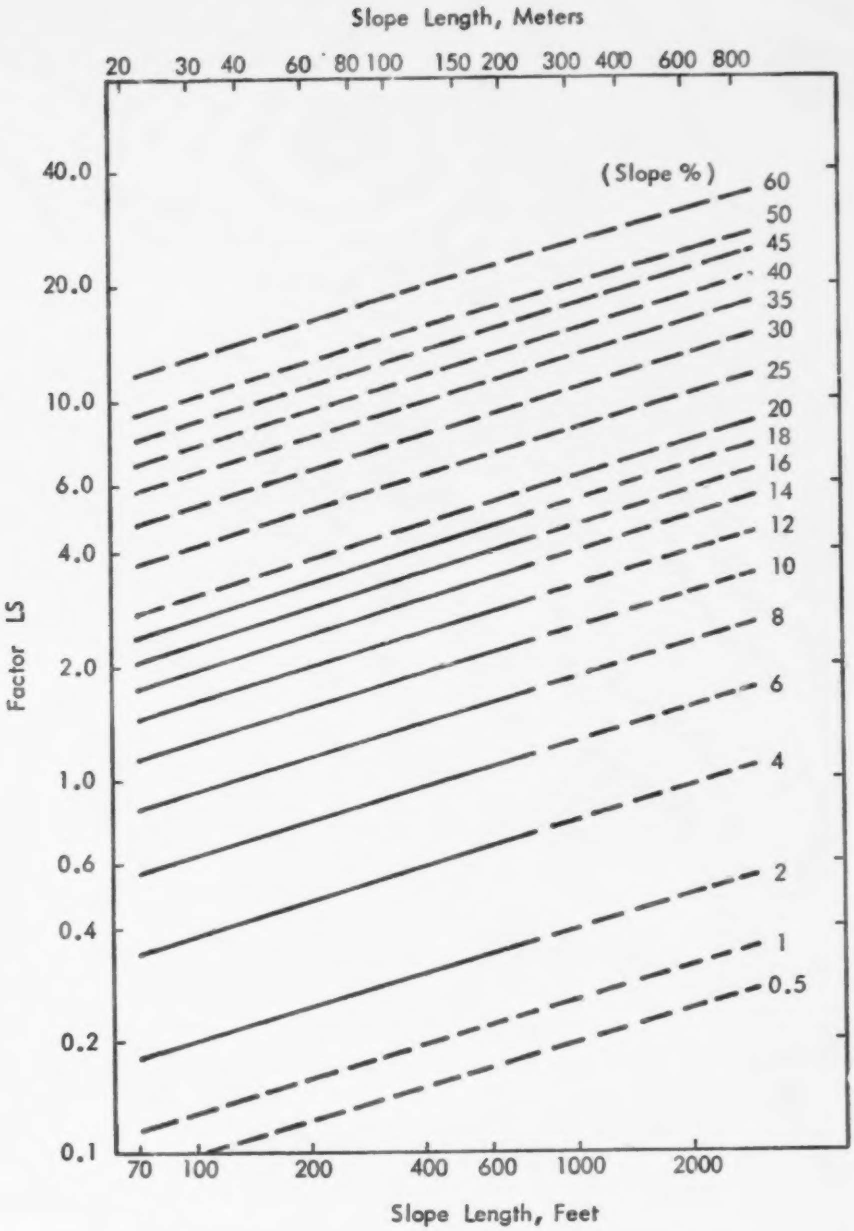

Figure 3-7. Slope effect chart applicable to Areas A-1 in Washington, Oregon, and Idaho and all of A-3[13,a,b]

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[a] See Figure 3-4.

[b] Dashed lines are extensions of LS formulae beyond values tested in studies.

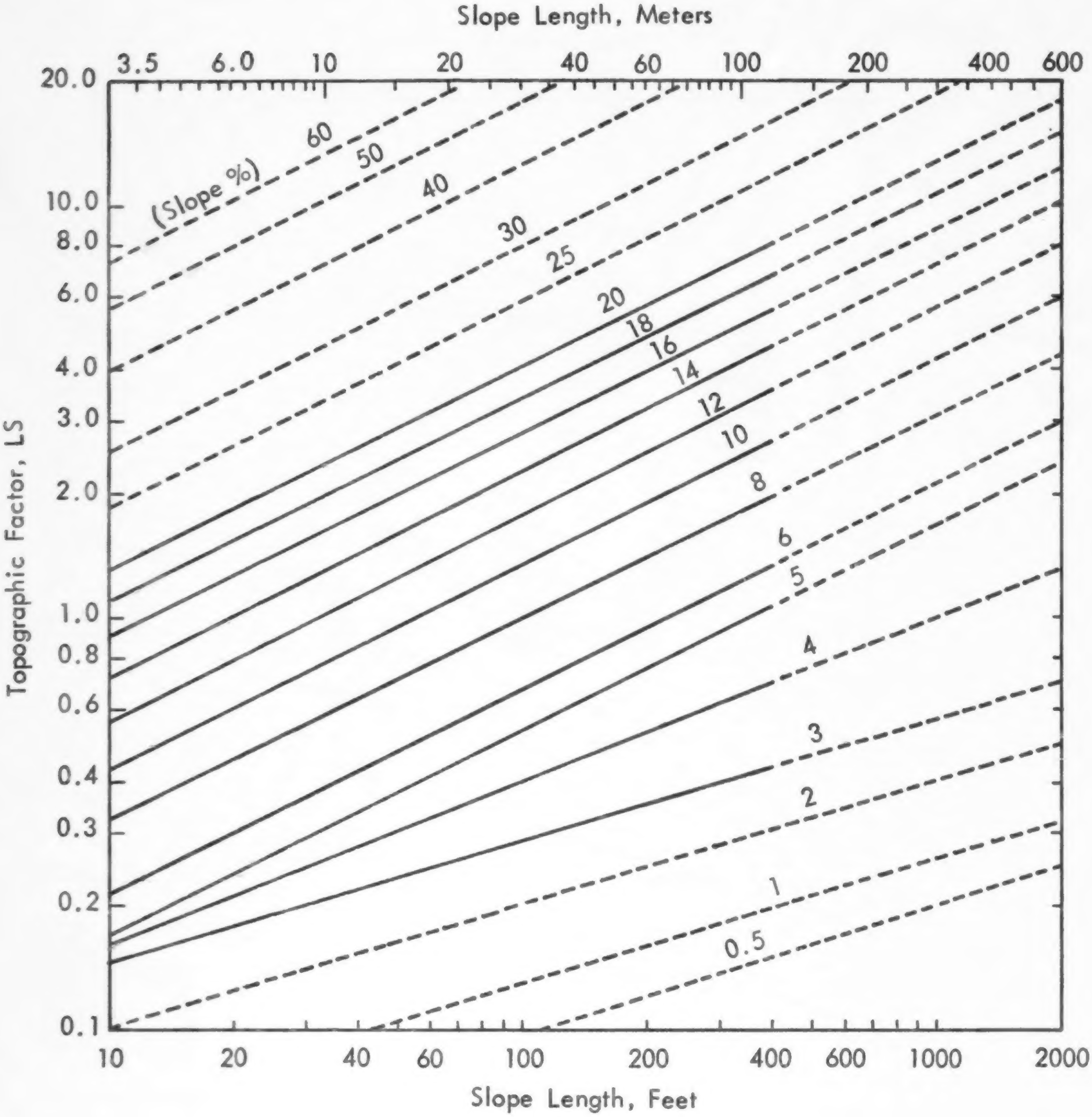

Figure 3-8. Slope--effect chart for areas where Figure 3-7 is not applicable[13,a/]

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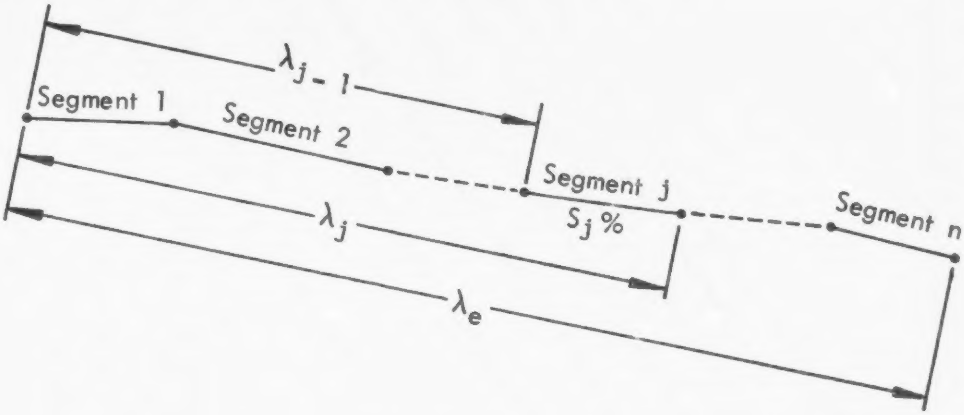
a/ The dashed lines represent estimates for slope dimensions beyond the range of lengths and steepnesses for which data are available.

3. Read across the point of intersection to the vertical axis. The number on the vertical axis is the LS value.

Slope-effect charts for irregular slopes - An irregular slope should be divided into a series of segments such that the slope gradient within each segment can be treated as uniform. The slope segments need not be of equal length. The total soil loss from the entire slope is calculated based on the effective LS value for the entire length of the irregular slope.

A family of curves shown in Figure 3-9 was designed to facilitate the determination of the LS factor for the irregular slopes ranging from 2 to 20%. The quantity plotted on the vertical scale is designated by the symbol U. Slope lengths, designated by λ, are plotted on the horizontal scale.

Assume an irregular slope with n segments illustrated as follows:



where λ_j = distance from the top of the entire slope (the point at which overland flow begins) to the lower end of the jth segment

λ_{j-1} = length of entire slope above segment j

λ_e = overall slope length

S_j = the slope gradient of segment j, in percent

The steps taken for calculating LS for irregular slopes using Figure 3-8 are:[15]

1. Enter on the horizontal axis with the value of λ_{j-1} (the slope length above segment j).

2. Move vertically to the curve with the appropriate percent slope for segment j.

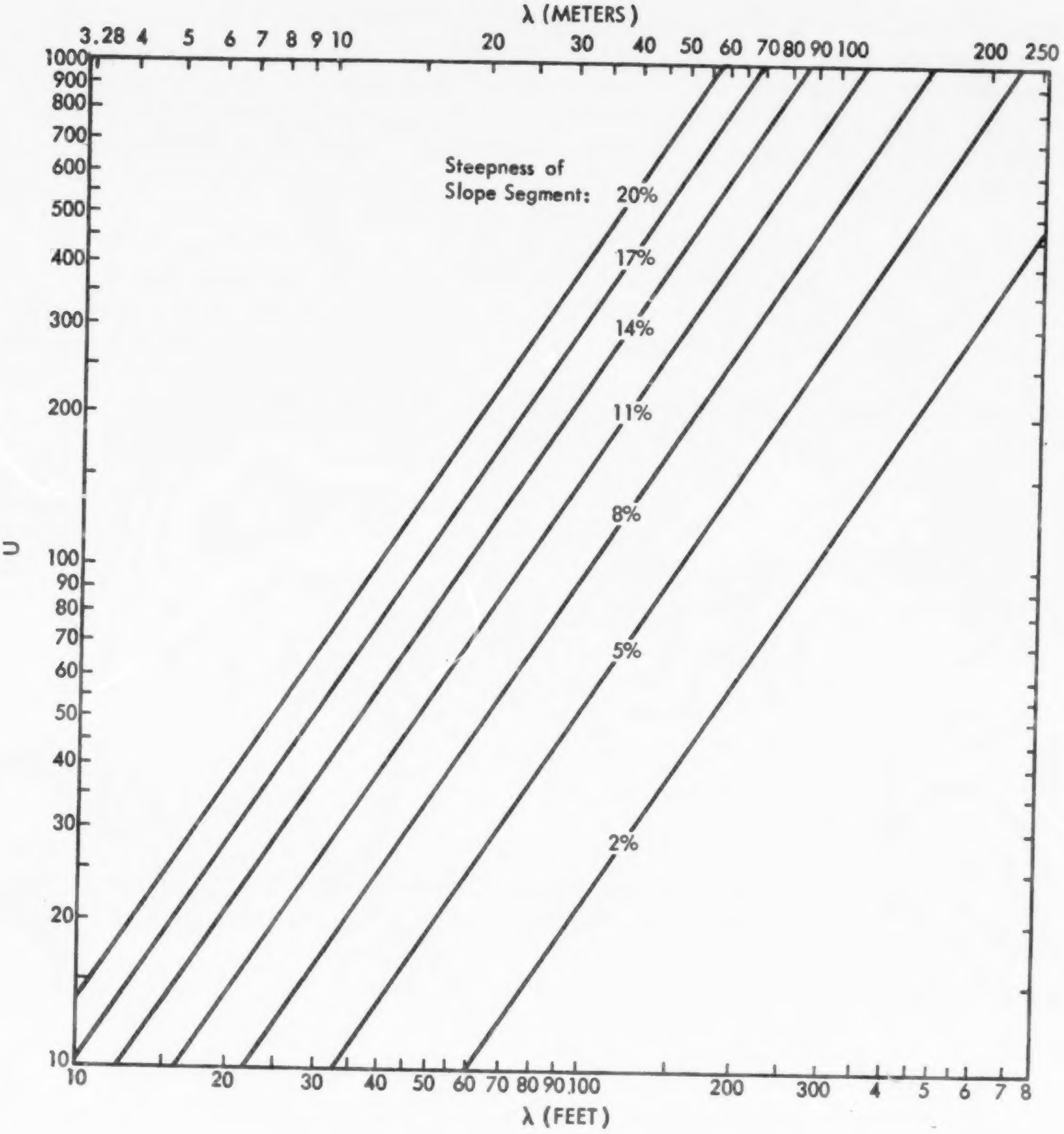


Figure 3-9. Slope effect chart for irregular slopes[15]

3. Read on the vertical scale the value of U_{1j}.

4. Enter the figure with the value of λ_j (the distance from the top of the entire slope to the lower end of the jth segment), repeat Steps 1 through 3 to obtain the value of U_{2j}.

5. Subtract U_{2j} from U_{1j}.

6. Repeat Steps 1 through 5 for each of the slope segments.

7. Sum n values of $U_{2j} - U_{1j}$, divide the sum by λ_e (the overall slope length). The result is the effective LS value for the entire length of the irregular slope.

Examples of the use of the above procedure to calculate LS factors for irregular slopes are given in Appendix C of this handbook.

The percentage of the total sediment yield that comes from each of the n segments can be obtained through a similar procedure. The relative sediment contribution of segment j, assuming constant soil erodibility for the entire slope, is given by:

$$\frac{U_{2j} - U_{1j}}{\sum_{j=1}^{n} (U_{2j} - U_{1j})}$$

For constructed slopes or mined slopes that cut into successive soil horizons, the soil erodibility K may vary considerably from upper to lower parts of a slope. When variations in slope gradient are associated with variations in soil erodibility along an irregular slope, K and $U_2 - U_1$ must be combined as follows to estimate the relative sediment contribution of segment j.

$$\frac{K_j \cdot (U_{2j} - U_{1j})}{\sum_{j=1}^{n} K_j \cdot (U_{2j} - U_{1j})}$$

3.2.5.4 The cover management factor (C) -

In the ULSE, the factor C represents the ratio of soil quantity eroded from land that is cropped or treated under a specified condition to that which is eroded from clean-tilled fallow under identical slope and rainfall conditions. C ranges in value from near zero for excellent sod or a well-developed forest to 1.0 for continuous fallow, construction areas, or other extensively disturbed soil.

Factor C for croplands - In order to evaluate the cover management factor for crops, five crop stage periods have been selected for relative uniformity of cover and residue effects within each period. These five periods are defined as follows:[9]

Period F: Rough fallow - Turn plowing to seeding.

Period 1: Seedbed - Seeding to 1 month thereafter.

Period 2: Establishment - From 1 to 2 months after seeding. (Exception: for fall-seeded grain, Period 2 includes the winter period and extends to 30 April in the North and 1 April in the South, with intermediate latitudes interpolated.)

Period 3: Growing crop - From Period 2 to crop harvest.

Period 4: Harvest, residue or stubble - From crop harvest to turn plow or new seedbed. (When meadow is established in small grain, Period 4 ends 2 months after grain harvest. Thereafter, it is classified as established meadow.)

The average cover factor C for the entire year or years of crop rotation is computed by crop stages. Input for calculation of C includes average planting and harvesting dates, productivity, disposition of crop residues, tillage, and monthly distribution of the erosion index R. The C value for each of these time periods is weighted according to the percentage of annual rainfall factor occurring in that period. The summation of these RC products for the entire year or years of crop rotation is then converted to a mean annual C.

Values of factor C for croplands are highly variable with rainfall pattern, planting dates, type of vegetative cover, seeding method, soil tillage, disposition of residues, and general management level. Ranges of C value for several types of vegetation and ground cover are listed in Table 3-3, in order of decreasing protection against erosion (increasing C value from near zero to 1).

The reader is advised to consult with state conservation agronomists of SCS for appropriate C values for crops in the local area. The reader is also referred to USDA-ARS Agriculture Handbook No. 282[9] for a listing of approximated C values for various crops at each crop stage, as well as a working table for derivation of average C value for periods of crop rotation.

Table 3-3. RELATIVE PROTECTION OF GROUND COVER AGAINST EROSION
(In order of increasing C factor)

Land-use groups	Examples	Range of "C" values
Permanent vegetation	Protected woodland Prairie Permanent pasture Sodded orchard Permanent meadow	0.0001-0.45
Established meadows	Alfalfa Clover Fescue	0.004-0.3
Small grains	Rye Wheat Barley Oats	0.07-0.5
Large-seeded legumes	Soybeans Cowpeas Peanuts Field peas	0.1-0.65
Row crops	Cotton Potatoes Tobacco Vegetables Corn Sorghum	0.1-0.70
Fallow	Summer fallow Period between plowing and growth of crop	1.0

Factor C for pasture, range and idle land - C values typical of permanent pasture, range, and idle lands, with varying cover and canopy conditions, are given in Table 3-4. These values were developed by Wischmeier.[16]

Factor C for woodland - Wischmeier[16] also estimated factor C for some woodland situations. Data are presented in Table 3-5.

Factor C for urban and road areas, construction and mining sites - On these areas and sites, the factor C represents the effect of land cover or treatment that may be used to protect soil from being eroded. Table 3-6[17] lists values of the factor C for various soil covers and treatments.

3 2.5.5 The practice factor (P) -

The factor P accounts for control practices that reduce the erosion potential of runoff by their influence on drainage patterns, runoff concentration, and runoff velocity.

For croplands, control practices refer to contour tillage, cross-slope farming, and contour strip-cropping. The practice value P is the ratio of soil loss from a specified conservation practice to the soil loss occurring with up- and downhill tillage, when other conditions remain constant. Tabl 3-7[13] shows P values for up and downhill farming, cross-slope farming without strips, contour farming, cross-slope farming with strips, and contour strip-cropping.

Terracing is also an effective practice to reduce soil erosion. The quantitative effect of terracing is accounted for in the slope length factor, since the horizontal terrace interval becomes the slope length, after the terraces are constructed.

3.2.5.6 Sediment delivery ratio (S_d) -

The sediment-delivery ratio, in this handbook, is defined as the fraction of the gross erosion which is delivered to a stream. The classical method for determining an average delivery ratio is by comparing the magnitude of the sediment yield at a given point in a watershed (generally at a reservoir or a stream sediment measuring station), and the total amount of erosion. The quantities of gross erosion from sloping uplands are computed by erosion prediction equation for surface erosion, and estimated by various procedures for gullies, stream channels, and other sources (see Section 3.3 of this handbook). The sediment yield at a given downstream point is obtained through direct measurements.

Table 3-4. "C" VALUES FOR PERMANENT PASTURE, RANGELAND, AND IDLE LAND[16,a]

Vegetal canopy Type and height of raised canopy[b]	Canopy cover[c] (%)	Type[d]	Cover that contacts the surface					
			Percent ground cover					
			0	20	40	60	80	95-100
Column no.	2	3	4	5	6	7	8	9
No appreciable canopy		G	0.45	0.20	0.10	0.042	0.013	0.003
		W	0.45	0.24	0.15	0.090	0.043	0.011
Canopy of tall weeds or short brush (0.5 m fall height)	25	G	0.36	0.17	0.09	0.038	0.012	0.003
		W	0.36	0.20	0.13	0.082	0.041	0.011
	50	G	0.26	0.13	0.07	0.035	0.012	0.003
		W	0.26	0.16	0.11	0.075	0.039	0.011
	75	G	0.17	0.10	0.06	0.031	0.011	0.003
		W	0.17	0.12	0.09	0.067	0.038	0.011
Appreciable brush or bushes (2 m fall height)	25	G	0.40	0.18	0.09	0.040	0.013	0.003
		W	0.40	0.22	0.14	0.085	0.042	0.011
	50	G	0.34	0.16	0.085	0.038	0.012	0.003
		W	0.34	0.19	0.13	0.081	0.041	0.011
	75	G	0.28	0.14	0.08	0.036	0.012	0.003
		W	0.28	0.17	0.12	0.077	0.040	0.011
Trees but no appreciable low brush (4 m fall height)	25	G	0.42	0.19	0.10	0.041	0.013	0.003
		W	0.42	0.23	0.14	0.087	0.042	0.011
	50	G	0.39	0.18	0.09	0.040	0.013	0.003
		W	0.39	0.21	0.14	0.085	0.042	0.011
	75	G	0.36	0.17	0.09	0.039	0.012	0.003
		W	0.36	0.20	0.13	0.083	0.041	0.011

---

[a] All values shown assume: (1) random distribution of mulch or vegetation, and (2) mulch of appreciable depth where it exists.

[b] Average fall height of waterdrops from canopy to soil surface: m = meters.

[c] Portion of total-area surface that would be hidden from view by canopy in a vertical projection (a bird's-eye view).

[d] G: Cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 5 cm (2 in.) deep.

W: Cover at surface is mostly broadleaf herbaceous plants (as weeds) with little lateral-root network near the surface and/or undecayed residue.

Table 3-5. "C" FACTORS FOR WOODLAND[16]

Stand condition	Tree canopy percent of area[a]	Forest litter percent of area[b]	Undergrowth[c]	"C" factor
Well stocked	100-75	100-90	Managed[d] Unmanaged[d]	0.001 0.003-0.011
Medium stocked	70-40	85-75	Managed Unmanaged	0.002-0.004 0.01-0.04
Poorly stocked	35-20	70-40	Managed Unmanaged	0.003-0.009 0.02-0.09[e]

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[a] When tree canopy is less than 20%, the area will be considered as grassland or cropland for estimating soil loss.

[b] Forest litter is assumed to be at least 2-in. deep over the percent ground surface area covered.

[c] Undergrowth is defined as shrubs, weeds, grasses, vines, etc., on the surface area not protected by forest litter. Usually found under canopy openings.

[d] Managed - grazing and fires are controlled.
Unmanaged - stands that are overgrazed or subjected to repeated burning.

[e] For unmanaged woodland with litter cover of less than 75%, C values should be derived by taking 0.7 of the appropriate values in Table 3-4. The factor of 0.7 adjusts for the much higher soil organic matter on permanent woodland.

Table 3-6. "C" FACTORS FOR CONSTRUCTION SITES[17]

Type of cover	C value
None (fallow)	1.00
Temporary seedings	
First 60 days	0.40
After 60 days	0.05
Permanent seedings	
First 60 days	0.40
After 60 days	0.05
After 1 year	0.01
Sod (laid immediately)	0.01

	Rate of application			Maximum allowable slope length	
Mulch	In metric tons per hectare	In tons per acre	C value	(ft)	(m)
Hay or straw	1/2	1/2	0.34	20	6
	1	1	0.20	30	9
	1-1/2	1-1/2	0.10	40	12
	2	2	0.05	50	15
Stone or gravel	14	15	0.80	15	5
	55	60	0.20	80	24
	120	135	0.10	175	53
	220	240	0.05	200	61
Chemical mulches					
First 90 days		[a]	0.50	50	15
After 90 days		[a]	1.00	50	15
Woodchips	2	2	0.80	25	8
	4	4	0.30	50	15
	6	7	0.20	75	23
	11	12	0.10	100	30
	18	20	0.06	150	46
	23	25	0.05	200	61

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[a] As recommended by manufacturer.

Table 3-7. "P" VALUES FOR EROSION CONTROL PRACTICES ON CROPLANDS[13]

Slope	Up- and down-hill	Cross-slope farming without strips	Contour farming	Cross-slope farming with strips	Contour strip-cropping
2.0-7	1.0	0.75	0.50	0.37	0.25
7.1-12	1.0	0.80	0.60	0.45	0.30
12.1-18	1.0	0.90	0.80	0.60	0.40
18.1-24	1.0	0.95	0.90	0.67	0.45

Measurements of sediment accumulations in reservoirs and sediment-load records in streams show wide variations in sediment yields from watersheds. Estimates show that as little as 5% and as much as 100% of the materials eroded in some watersheds may be delivered to a downstream point. Estimates of the delivery ratio for some specific watersheds, particularly in the humid sections of the country, can be obtained from the Soil Conservation Service, USDA.

Many delivery-ratio analysis studies were aimed at finding measurable influencing factors that can be related to sediment-delivery ratio. A popular means of developing such information is by statistical analysis using the sediment-delivery ratio as the dependent variable and measurable watershed factors as the independent, or controlling variables. As pointed out in Section 3.2.1.3 of this handbook, many physical and hydrological factors of watersheds may influence sediment-delivery ratios. Some are more pronounced in their effect than others. Some lend themselves to quantitative expression whereas others do not. To this date, however, the science of sedimentology has not progressed to the state where the relative influence of each of the individual physical and hydrological factors has been evaluated, and their relative influence on the delivery ratio of sediment has not been determined to the degree of accuracy desired. Nevertheless, empirical relationships for delivery ratios have been proposed and are presented below. Estimates of sediment loading can be made through the use of these relationships, but such estimates should be tempered with judgment and consideration of other influencing factors which are not included in the quantitative expressions. The user is encouraged to consult with local experts and should use local data when available.

Sediment delivery ratio for construction sites - The MITRE Corporation reported[18] that the sediment-delivery ratio for construction sites can be approximated by a function of the overland distance between the construction site and the receptor water.

The format of the sediment delivery ratio proposed by MITRE for construction sites has the following form:

$$S_d = D^{-0.22} \qquad (3\text{-}2)$$

where D = overland distance between the erosion site and the receptor water, in ft

The above equation was empirically derived from available data. The data base for the derivations has values of D from 0 to 800 ft. MITRE suggests that this function should be subjected to further testing, particularly in areas of the Midwest and Central U.S. from which no data were obtained and used for deriving the above equation.

Sediment delivery ratio for other intensely distrubed sites - For mining sites, or for forestland areas such as logging roads, fire lanes, sediment delivery ratio relationships have not yet been established due to lack of systematically measured data. It is suggested, however, that the delivery ratio developed by MITRE and expressed in Eq. (3-2) be used as the first approximation for these sites. This needs to be validated when appropriate data become available.

Sediment delivery ratio from relatively homogeneous basins - Sediment delivery ratios have been evaluated in many areas of the country, particularly the eastern half of the United States. The delivery ratio usually depicts a general trend in basins that are relatively homogeneous with respect to soils, land cover, climate, and topography. The Soil Conservation Service[19] has reported an analysis of data from stream and reservoir sediment surveys from widely scattered areas.

This analysis shows that sediment delivery ratios vary inversely with "drainage basin size". It also indicates the effect of soil texture of upland soil on the sediment delivery ratio.

The delivery ratio relationships reported by SCS[19] were utilized by the MRI study group in developing delivery ratios for sediment loading to watercourses. The result is shown in Figure 3-10. The horizontal scale of the figure is the reciprocal of drainage density which is defined as the ratio of total channel-segment lengths (accumulated for all orders within a basin) to the basin area. The reciprocal of drainage density may be thought of as an expression of the closeness of spacing of channels, or the average distance for soil particles to travel from erosion site to the receptor water.

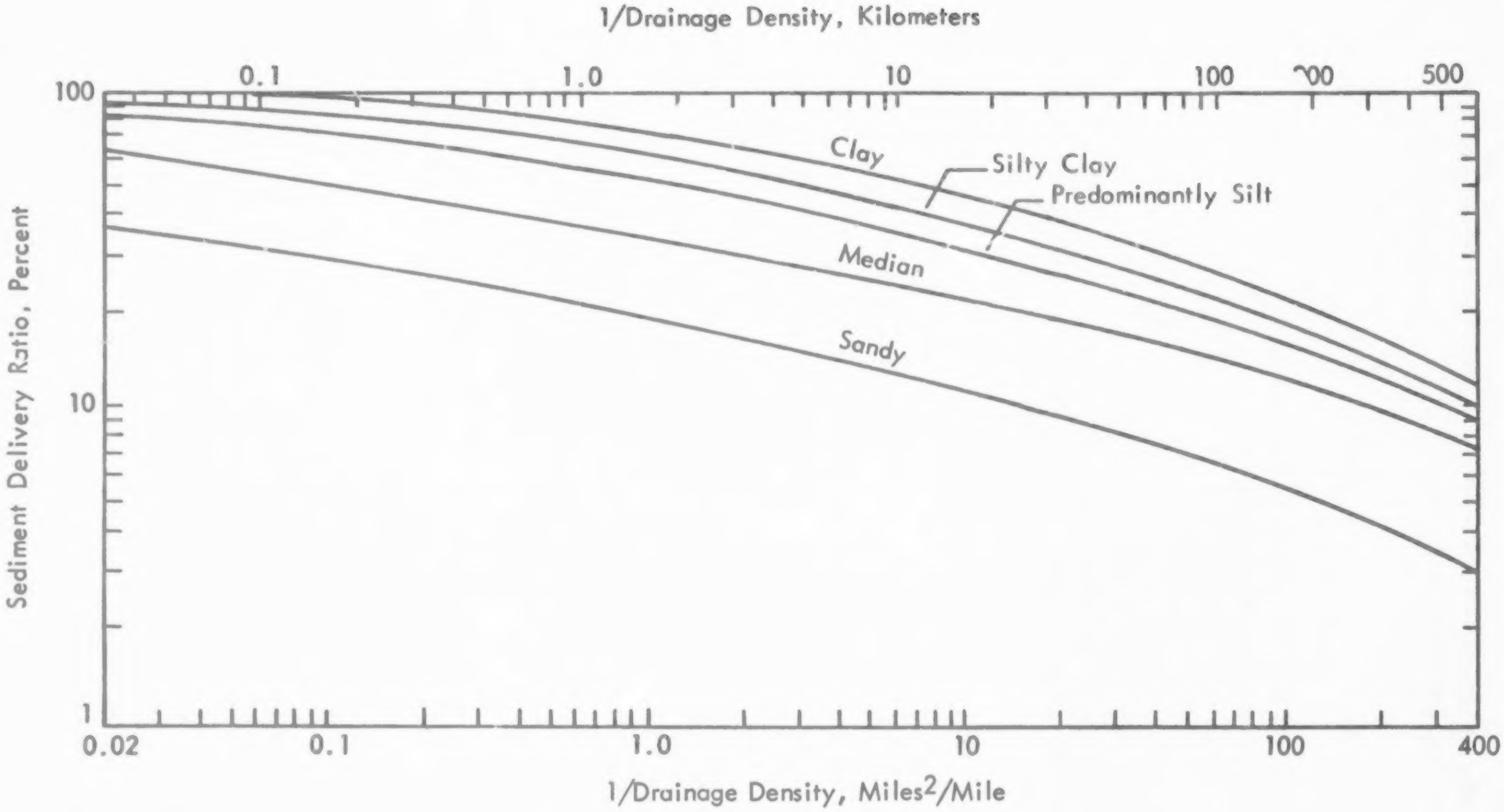

Figure 3-10. Sediment delivery ratio for relatively homogeneous basins[a]

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[a] Source: Midwest Research Institute.

The delivery ratio relationship shown in Figure 3-10 also takes into account the effect of soil texture. For example, if soil texture of upland soil is essentially silt or clay, the sediment delivery ratio will be higher than when the soil texture is coarse.

The delivery ratio relationships in Figure 3-10 need to be further validated by acquisition of new data. They also need to be improved in the future to include other factors relative to deposition mechanisms.

The following steps are to be used to obtain delivery ratio (S_d) from Figure 3-10.

1. Enter the figure on the horizontal axis with the value of the reciprocal of drainage density (1/DD).

2. Move vertically from the value of 1/DD to where it intersects the curve for the appropriate soil texture.

3. Read across from the point of intersection to the vertical axis. That number represents the delivery ratio, S_d.

Values of drainage density - A great range of values of drainage density exists in the United States, from 2 km/km^2 (3 miles/miles^2) for the Appalachian Plateau Province[20] to 500 km/km^2 (800 miles/miles^2) in Badlands at Perth Amboy, New Jersey.[21] In general, according to Strahler,[22] low drainage density is found in regions of highly resistant or highly permeable subsoil materials, under dense vegetative cover, and where relief is low. High drainage density is favored in regions of weak or impermeable materials, sparse vegetation, and mountainous relief.

Some typical values of drainage density for various locales in the U.S. are given in Table 8-8. Local drainage density figures may be obtained from agencies such as the Geological Survey and the Army Corps of Engineers.

Measurements of drainage density can be made from a topographic map with a planimeter and chartometer. Care must be taken to include all permanent stream channels to their upper ends by checking in the field or aerial photographs in verification of topographic maps. A rapid approximation method for determining drainage density is suggested by Carlston and Langbein.[27]

Table 3-8. TYPICAL VALUES OF DRAINAGE DENSITY

Location	Drainage density		Reference
	km/km^2	mile/mile^2	
Appalachian Plateau Province	1.9-2.5	3.0-4.0	Smith (20)
Central and eastern United States	5-10	8.0-16.0	Strahler (23)
Dry Areas of the Rocky Mountain Region	31-62	50-100	Melton (24)
The Rocky Mountain Region (except the above)	5-10	8.0-16	Melton (24)
Coastal ranges of southern California	12-25	20-40	Smith (20) Melton (24) Maxwell (25)
Badlands in South Dakota	125-250	200-400	Smith (26)
Badlands in New Jersey	183-510	310-820	Schumn (21)

3.2.5.7 Summary of applicabilities of source characteristic factors -

The preceding paragraphs indicate that assessment of sediment loadings from surface erosion requires quantitative information on soil erodibility, rainfall and snowmelt erosivity, topography, vegetative cover, conservation practices, and sediment delivery ratio. Applicability of each factor varies with specific location of the site and also with type of land disturbance. Table 3-9 gives a total summary of variations in application of those factors.

3.2.5.8 Limitations of the loading function -

The USLE predicts soil losses from sheet and rill erosion. It does not predict sediment from gullies, streambank erosion, landslides, road ditches, irrigation, or from wind erosion. The USLE was developed primarily for croplands, and has been chiefly based upon experimental plot data from the areas east of the Rocky Mountains. The loading function therefore is best defined for these areas of use. For croplands in the western United States and sources outside agriculture such as silviculture, construction, and mining, the factors have not been systematically developed, which seriously affects the ease of using the USLE for such sources.

Specific limitations include:

R: Research is needed to determine the effective R values more accurately in both the east and west of the continental United States.

L and S: The relationships on which the slope effect charts are based were derived from data taken on slopes not exceeding 20% and length not exceeding 400 ft. How far these dimensions can be exceeded before those relationships change has not been determined.

C: More work is needed to improve definitions of cover factor, particularly for areas outside agriculture, such as undisturbed forest, harvested or burned forests, logging roads, mining sites, rangeland, and construction sites.

P: The reported values of the practice factor have been limited to cropland. Definition of practice factor values is needed for various conservation practices on silviculture, mining, construction and other areas outside agriculture.

S_d: The science of sedimentology has not progressed to the state where the sediment-delivery ratio can be predicted to the degree of accuracy desired. In addition, for the benefit of pollution analysis, delivery ratios should be developed for prediction of sediment loadings reaching the "receptor waters" rather than "reservoirs."

Table 3-9. SUMMARY OF APPLICABILITY OF CHARACTERISTIC FACTORS

Land use		Source characteristic factor	Regions in the United States	
Extent of land disturbance	Example		Eastern states and Hawaii	Western states
Zero to moderately disturbed	Growing forests Rangeland Pastureland Cropland Orchards	R	Affected by rainfall only; use Figures 3-2 or 3-3.	Affected by rainfall, some areas also by snowmelt (see note below).
		K	Erodibility of topsoils.	Erodibility of topsoils.
		LS	Use Figure 3-8 for natural slope steepness and slope length (except terracing).	Use Figure 3-7 for some areas in Washington, Oregon, Idaho, and California; the remainder use Figure 3-8 (except terracing).
		C	For croplands and orchards, C's are determined locally by SCS. For forests, use Table 3-5; rangeland and pastureland, use Table 3-4.	For croplands and orchards, C's are determined locally by SCS. For forests, use Table 3-5; rangeland and pastureland, use Table 3-4.
		P	For croplands, use Table 3-7; others = 1.0.	For croplands, use Table 3-7; others = 1.0.
		S_d	Assume relatively homogeneous land use components; use Figure 3-10.	Assume relatively homogeneous land use components; use Figure 3-10.
Intensively disturbed	Construction sites Mining sites Logging roads Fire lanes	R	Affected by rainfall only; use Figures 3-2 or 3-3.	Affected by rainfall, some areas also by snowmelt (see note below).
		K	Erodibility of topsoils and subsoils.	Erodibility of topsoils and subsoils.
		LS	Use Figure 3-9 for irregular slopes.	Use Figure 3-9 for irregular slopes.
		C	Use Table 3-6.	Use Table 3-6.
		P	Equals 1.0.	Equals 1.0.
		S_d	Use Eq. (3-2)	Use Eq. (3-2)

Note: See Section 3.2.5.1 for "Methods for Developing Annual R Values for the Western United States."

The loading function in Eq. (3-1) and supporting data in tables and figures were designed to predict longtime average loadings for specific conditions. Sediment loading for a specific year may be substantially greater or smaller than the annual averages because of differences in number, size, and timing of erosive rainstorms, and in other weather parameters. The reader is referred to Table 11 of USDA Agriculture Handbook 282[9/] for a listing of 50, 20, and 5% probability values of R factor at 181 key locations in the area east of the Rocky Mountains. These may be used for further characterization of soil-loss hazards.

Due to the uncertainties embedded in factor values, it is advisable that sediment loading computed by Eq. (3-1) be accepted as reasonable estimates rather than as absolute data. Table 3-10 lists the best estimate of the range of accuracy for Eq. (3-1) and available supporting data. The range figures pertain to annual average. For a specific year, the range may be much larger than those given.

Table 3-10. ESTIMATED RANGE OF ACCURACY OF SEDIMENT LOADS FROM SURFACE EROSION

Predicted loading (MT/ha/year)	Estimated range of accuracy (MT/ha/year)
0.1	0.001 ~ 1.0
1	0.1 ~ 5
10	5 ~ 15
100	50 ~ 150
1,000	500 ~ 1,500

3.2.6 Source Characteristic Factors for Predicting Maximum and Minimum Sediment Loadings

The loading function in Eq. (3-1) can be used to predict sediment loading other than annual averages. Variations of the loading rate are embedded in rainfall factor R and cover factor C. The evaluation procedure is illustrated in the following examples.

Example 1: Variations caused by rainfall factor alone - The rainfall erosion index R varies within a year, as shown in percent erosion index curves in Appendix A. For lands where cover factor is relatively constant, such as woodland and grassland, temporal distribution of rainfall factor R governs temporal variations in erosion.

Figure 3-11 shows an example of monthly distribution of percentages of annual R values. This distribution curve is for parts of Michigan, Missouri, Illinois, Indiana, and Ohio based on Curve 16 in Figure A-2d. The following steps are required for evaluating monthly variation of R values.

1. Read the percent of annual erosion index, at the predetermined time interval, on the appropriate erosion index distribution curve (for this specific example, Curve 16 on Figure A-2d in Appendix A).

2. For each time interval, subtract the reading of the first date from that of the last date.

3. Results of Step 2 are the percents of annual index that are to be expected within the particular periods. Use these data for plotting distribution curve. The percent average daily is 0.274, which is obtained by dividing 100 (percent) by 365 (days in a year).

The curve in Figure 3-11 indicates that, if other factors hold constant, soil erosion in this area would have its maximum from 20 June to 20 July, and minimum from late December to late January.

One estimates that, based on the R distribution in Figure 3-11, the maximum daily loading rate during a 30-consecutive-day period for woodland and grassland in this particular area is approximately 2.5 times that of average daily loading rate for 1 year; the minimum daily rate during a 30-consecutive-day period is approximately one-fourth of the average daily rate.

Example 2: Variations caused by the combined effects of rainfall factor and cover factor - For croplands, where soils are tilled and surface conditions change drastically from one crop stage to another, evaluation of erosion variation should include both the R factor and C factor.

Required steps to achieve such evaluations are:

1. Determine average dates of each crop stages.

2. Determine C factor values for each crop stage from such information as productivity, disposition of crop residues and tillage.

3. Obtain monthly distribution of R.

4. Multiply C factor values by the R value of the corresponding period.

Variations of RC products are the temporal variations of sediment loading.

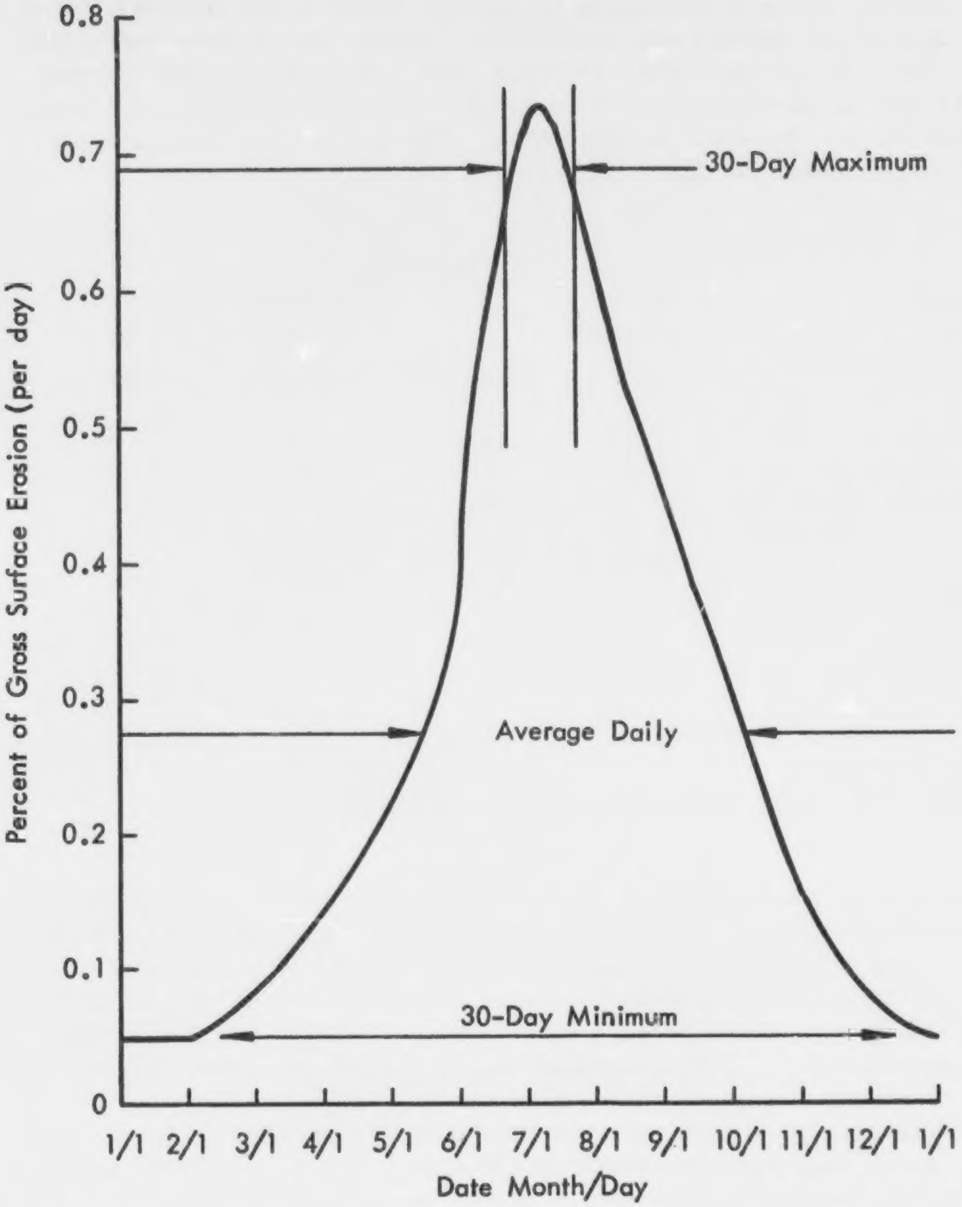

Figure 3-11. Projected variation of soil erosion for lands with constant cover factor, in parts of Michigan, Missouri, Illinois, Indiana, and Ohio[a]

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[a] Source: Midwest Research Institute.

In this example, temporal variation of surface erosion rate for continuous cornland in central Indiana was calculated. Again, the erosion index distribution Curve No. 16 on Figure A-2d was used. Assumptions were conventional tillage, a yield average of 40 to 59 bu of corn per acre, and cornstalks left on the field after harvesting. The dates, C values, and percent of erosion index for five-crop stages, and RC products are:

Crop stage, starting-ending date	Cover factor, C[a]	Percent R		RC product
		Reading[b]	Percent in the period	
Turn plowing, 5/1-5/19	0.55	13.8	5.7	3.14
Seeding, 5/20-6/19	0.70	19.5	16.5	11.55
Establishment, 6/20-7/19	0.58	36.0	21.3	12.35
Growing crop, 7/20-10/9	0.32	57.3	33.7	10.78
Harvest and stubble, 10/10-4/30	0.50	91.0	22.8	11.40
Total			100	49.22

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[a] Reference source: USDA-Agricultural Research Service Handbook No. 282,[9] Table 2.

[b] Reading from Figure A-2d (Curve 16) for starting date.

The annual C factor is estimated at 0.49. Temporal variation of surface erosion rate, in terms of percent of annual total, is shown in Figure 3-12. It is seen that the maximum erosion from this continuous cornland would occur in mid-June through mid-July, nearly identical to the period of maximum erosion with constant soil cover (Figure 3-11). The 30-day maximum is approximately 3.2 times average daily, which is higher than the previous (constant C factor) case due to the magnifying effect caused by the overlapping of a high R period with a high C period. Figure 3-12 also shows that minimum erosion would occur during the winter season; the 30 day minimum is one-fourth of the average daily load.

3.2.7 Source Areal Data

Information and data of considerable variety are needed to assess sediment loading by surface erosion from various sources. Pertinent source characteristic data including soil erodibility, rainfall erosivity, slope length, slope gradient, vegetative cover, conservation practices, and delivery ratio, have been presented in the previous sections. This section presents sources of data relevant to acreages of land use and land disturbance.

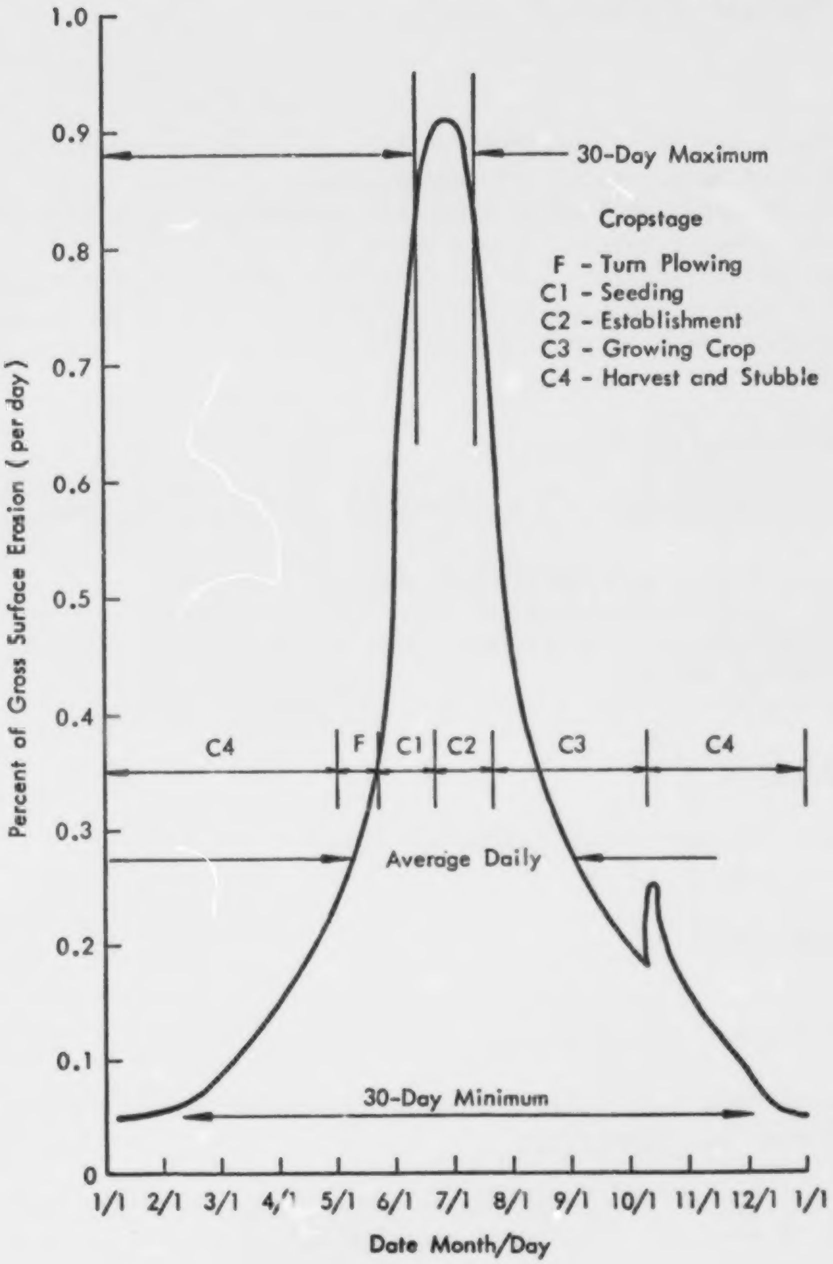

Figure 3-12. Projected variation of soil erosion on continuous corn lands in central Indiana[a]

Source: Midwest Research Institute.

The following are sources of areal data which are pertinent to assessing sediment loadings from various nonpoint sources.

Land use -

"Conservation Needs Inventory" - Soil Conservation Service
"Census of Agriculture" - Bureau of Census
State cropland and livestock reports - State Agriculture Department
Forest survey reports - Forest Service
Range survey reports - Soil Conservation Service, Forest Service
Forest cutting and fire reports - Forest Service, State Foresters
"Watershed Conservation and Development Field Data" - Bureau of Land Management

Housing construction -

Statistical Yearbook - U.S. Department of Housing and Urban Development
County and City Data Book - U.S. Bureau of Census
"U.S. Census of Population and Housing" - U.S. Bureau of Census
"Housing Authorized by Building Permits and Public Contracts" - U.S. Bureau of Census
"Construction Report" - U.S. Bureau of Census

Mining activities -

Mineral Yearbook - U.S. Bureau of Mines
Mining permits - State

Highways and roads -

U.S. Federal Highway Administration
State Highway Department

The following data sources are particularly pertinent to assessment of surface erosion for large areas.

Data for agricultural lands--the Conservation Needs Inventory (CNI) - The CNI is one of the major sources of data for agricultural land in the United States. The first inventory was made in 1958 to 1960 and updated in 1967. The objective of the inventory was to develop current, detailed data on land use and conservation treatment needs on rural land and to obtain data on watershed project needs on both privately and publicly owned land in the U.S. The inventory includes all acreage except urban and built-up areas and land owned by the federal government, other than cropland operated under lease or permit.

Inventoried lands are compiled by county in terms of land use, land capability class and subclass,* and conservation treatment needs as shown in Table 3-11. The seven major rural land use categories are subdivided into 18 secondary land use classifications and current (1967) conservation treatment needs. Each group is inventoried according to land capability classes and subclasses.

It is important to note that not all land was classified or inventoried in the CNI. For the noninventoried land (including federal noncropland, urban buildup, and small water bodies), there has been thus far no information concerning use of land by capability. For most regions the proportion of total land in the noninventory group is not significant. However, in the western states the proportion of this group may be very high.

Copies of state inventories may be obtained from the State Conservation Needs Inventory Committee, and/or University Agricultural Extension Service. Magnetic tapes of the inventory are available from the Statistical Laboratory, Iowa State University, Ames, Iowa.

The U.S. Soil Conservation Service in 1972 solicited soil scientists in the United States for the soil data relevant to surface erosion, in format compatible with the format of CNI. Data are reported by Land Resources Area** (LRA) and by land capability class and subclass. For all LRA's east

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* Land Capability Classification is one of a number of interpretive grouping of soil survey maps made primarily for agricultural purposes.

In this classification, the arable soils are grouped according to their potentialities and limitations for sustained production of the common cultivated crops that do not require specialized site conditioning or site treatment. Nonarable soils (soils not suitable for long-time sustained use for cultivated crops) are grouped according to their potentialities and limitations for the production and permanent vegetation and according to their risks of soil damage if mismanaged.

The capability classification provides three major categories: (a) capability unit; (b) capability subclass; and (c) capability class. The reader is advised to consult with State Conservation Needs Inventory for detailed descriptions of classifications.

** Land Resource Areas (LRA), as delineated by the Soil Conservation Service, U.S. Department of Agriculture, are broad, geographic areas having similar patterns of soil (including slope and erosion), climate, water resources, land use, and type of farming. Delineation and description of LRAs are available in USDA-SCS, Agriculture Handbook No. 296, "Land Resource Areas of the United States," December 1965, and USDA-ERA series on "The Look of Our Land--An Airphoto Atlas of the Rural United States."

Table 3-11. LAND USE AND TREATMENT NEEDS CATEGORIES OF THE CONSERVATION NEEDS INVENTORY

Primary use classification	Secondary use classification	Treatment classification
Cropland in tillage rotation	Corn and sorghum	Treatment adequate
	Other row crops	Treatment needed--nonirrigated
	Close-grown crops	Residue and annual cover
	Summer fallow	Sod in rotation
	Rotation hay and pasture	Contouring
	Hayland	Strip-cropping or terracing diversion
	Conservation use only	Permanent cover
		Drainage
	Idle	Treatment needed--irrigated
		Cultural and management practices
		Improved system
		Water management
Other cropland	Orchards, vineyards and bush fruit	Treatment adequate
	Open land formerly cropped	Treatment not adequate
Pastureland		Treatment adequate
		Treatment unfeasible
		Needs change in land use
		Protection only
		Improvement only
		Improvement and brush control
		Reestablishment of vegetative cover
		Reestablishment and brush control
Rangeland		Treatment adequate
		Treatment unfeasible
		Needs change in land use
		Protection only
		Improvement only
		Improvement and brush control
		Reestablishment of vegetative cover
		Reestablishment and brush control

Table 3-11. (Concluded)

Primary use classification	Secondary use classification	Treatment classification
Forestland	Commercial	Treatment adequate Noncommercial--stand establishment and reinforcement Commercial--stand establishment and reinforcement
	Noncommercial	Commercial--timberstand improvement
Forestland grazed	Commercial	Treatment adequate Forage improvement
	Noncommercial	Reduction or elimination of grazing
Other land	On farms	Treatment adequate
	Not on farms	Treatment not adequate

of the continental divide, information solicited includes name of dominant soil, dominant slope length, dominant slope percent, and K factor. These data were reported in Data Form 1.

For LRAs west of the continental divide, where K factors had not been developed before the survey, information solicited includes dominant soil name, dominant slope length, slope percent, and estimated soil losses (tons/acre/year) from selected cropping systems. Data were solicited in Form 1W.

For convenience of use, the MRI study group has combined factors in Form 1 and calculated K·LS indexes for various land capability classes and subclasses for LRAs in the areas east of the continental divide. Values of the K·LS index, and questionnaire returns in Form 1W (for LRAs west of continental divide) are presented in the Appendices D and E, respectively, of this handbook. These data can be used together with land-use data in the State Conservation Needs Inventory for assessing gross erosion from agricultural lands in large areas.

Data for commercial forests - The most recent data on state and national levels are presented in "The Outlook for Timber in the United States," U.S. Department of Agriculture, Forest Service, Forest Resource Report No. 20, October 1973. This is a report on the nation's timber supply and demand situation and outlook, related primarily to the commercial timberlands in the U.S. that are suitable for production of timber crops. This report provides statistical data, as of 1970, on the current area and condition of the nation's forestland, inventories of standing timber, and timber growth and removals by individual states. Information is also included on recent trends in forestland and timber resources, trends in utilization of the nation's forest for timber and other purposes, and trends in consumption of wood products. This report represents the latest in a series of similar timber appraisals prepared by the Forest Service in the past.

If more local detail data are needed, they likely can be provided by the forest and range experiment stations. An important timber resources inventory on a local level available from the forest and range experiment stations is "Forest Statistics" (or "The Timber Resources"). The recent publications present inventories of timber resources on the state and county levels. The forest resource data and the accompanying discussions of forest area, volume, growth, and cut are useful for planners.

Despite the availability of considerable information on the United States timber inventory, there are important gaps in information necessary to assess pollutant loadings from forested areas. There is far more information available today concerning standing timber volume on forestland than there is concerning soil and topographic characteristics, the acreage of forest harvested, method of harvest, mileage of roads built and maintained, percent canopy and ground cover situation, and current soil and water conservation practices. One possible method of obtaining such information is through personal contact with local knowledgeable persons. The following are individuals who may be able to supply such needed data:

U.S. Forest Service

Resource management staff officers
District rangers
Forest supervisors
Regional foresters

U.S. Bureau of Land Management

State director
District manager

State and local agencies

State foresters
County foresters

Private forest industries

Data for mining and construction activities - The extent of construction and mining activities in a given locale can be estimated directly from sources such as building permits, construction reports, and mining permits. Similar data also can be obtained from some other sources, such as census data for housing units, highways, roads, utility transmission lines, etc., in which data are assembled periodically. Data gathered in different years can be translated into average annual acreages of land being disturbed by construction activities.

For example, the census in County and City Data Book, U.S. Department of Commerce, Bureau of the Census, includes the total number of housing units between 1967 and 1972. Also given are the number of units in single family units and the number in multiple units. From these figures the average annual number of new single and multiple dwelling units can be determined. With actual data or an approximation of acreage per housing unit, one may estimate the average annual acres of land used for new housing.

Construction activities for a given site are generally of limited duration, and so is sediment production. MRI economists estimated the average duration of construction to be:

6 months for residential buildings,
11 months for nonresidential buildings, and
18 months for nonbuilding construction.

3.3 SEDIMENT LOADINGS FROM OTHER SOURCES: GULLIES, STREAMBANKS, AND MASS SOIL MOVEMENT

3.3.1 Overview

3.3.1.1 Gully erosion -

Gully erosion is caused by temporary concentration of runoff during and immediately after rainfall. Sediment production from gullies is accomplished by scouring on the bottom or sides by running water, by slides of materials into gullies from the side, and by erosion over the well-defined headscarp.

Gully erosion is common to most regions in the United States. Expansion of gully development is most vividly apparent in arid and semi-arid areas such as southwestern U.S. where climatic changes are easily expressed in network changes, and also in those areas where the influence of man has been substantial or rapid, or both.

Gullies usually are found on slopes greater than 5 degrees. Gullies are especially active during the rainy season, and are particularly well-developed on the margins of uplands composed of highly friable sandstones.

Development of gullies is associated with improper land use and severe climatic events. The effect of land use on gully development is connected with modification of land cover and soil conditions, and subsequent changes in runoff patterns. Gullies have developed following the removal of trees on the lower part of the sides of glacial troughs, and following compaction of ground, change in topsoil, and changes in infiltration characteristics. The impact of land use on gully development is most striking when original plant cover on steep slopes is removed and runoff occurs with little impediment.

Climatic fluctuations also may cause gully development. Climatic fluctuation may cause disappearance of vegetation cover, and lead to vivid gullying activities.

Sediment production from gully development has been described for some regions in the U.S.[28,29] The quantity, though often large, is usually less than that produced by surface erosion. However, economic losses from dissection of uplands, damage to roads and drainage structures, and deposition of relatively infertile overwash on flood plains are disproportionately large. Technical procedures for evaluation of gully erosion are available in Soil Conservation Service, "Procedure for Determining Rates of Land Damage, Land Depreciation, and Volume of Sediment Produced by Gully Erosion," SCS Technical Release No. 32 (1966).

The prediction of gully growth has thus far received little attention, although some studies have developed empirical prediction procedures for specific localities.

3.3.1.2 Streambank erosion -

In the streambank erosion process, energy from streamflow, ice, and floating debris, and the force of gravity are applied to the streambank and streambed. If the energy is greater than the resistance of soil particles forming the channel, erosion results. Brown[2] suggests that in most forest and range country and in areas with less than 51 cm (20 in.) of precipitation annually, channel-type erosion (including gully, streambank, etc.) generally produces the greater part of the sediment. Where a watershed is primarily agricultural and has more than 51 cm (20 in.) of precipitation, a major part of the sediment production is generally from sheet erosion. Gottschalk[30] suggests that streambank erosion is dominant in the semiarid and arid areas of the United States and in the mountainous areas of the Central and South Pacific Coast regions. Anderson[31] estimated sediment yields from the North Coast watersheds of California, and the Williamette Basin of western Oregon, and concluded that sediment contribution from streambank erosion in that part of the country is greater than from other sources combined.

In 1969, the Corps of Engineers, in conjunction with Soil Conservation Service personnel, completed the "National Assessment of Stream Bank Erosion."[32] All districts in the nation provided information on the amounts of streambank erosion in their areas. Stream density by land resource area was used to determine total stream miles and bank miles. Estimates were then made on how many of these banks erosion was negligible, moderate, and serious. Damages were determined at the site where erosion occurred and where the ensuing sediment was deposited. Cost of treatment was calculated for both moderate and serious cases.

A report on the nationwide assessment was issued by the Corps in October 1969. Regional inventory reports are available from appropriate district offices.

3.3.1.3 Mass soil movement -

Mass soil movement is the downslope movement of a portion of the land surface under the effect of gravity. Such movements may take the form of landslide, mudflow, or downward creep of an entire hillside, and contribute to sediment loadings to surface waters. In many areas this source of supply is unimportant. However, mass soil movement may constitute the dominant process of erosion in areas with exceptionally steep slopes, high rainfall, or low-strength soil, such as that of mountainous areas of western North America, as well as of southern California. In such areas, soil may remain in place as the result of a delicate balance between forces tending to cause downslope movement and various forces tending to resist it. Any disturbance may upset this delicate balance and result in initiation or acceleration of mass soil movement.

Landslide is influenced by the slope of the land, composition of soil, and water content of the soil. Dyrness[33/] indicated that stony soils from basalt and andesite were 14 to 37 times more stable than those from tuffs and breccias, which are volcanic parent materials, and normally weather rapidly to silts and clays. Silts and clays can retain large quantities of water. The water adds to the soil burden and reduces its strength, thus promoting landslides. In Oregon, landslides normally occur near peak stream flow from winter storm runoff when the water content of soil is at the maximum.

Man's activities may play an important role in initiation and acceleration of mass soil movements. In a review of mass erosion research in the western United States, Swanston[34/] made the following statements about the effect of disrupting activities of man on mass soil movements:

> "Road building stands out at the present time as the most damaging activity. Soil failures relating to this activity are the result primarily of slope loading from road fill and sidecasting, inadequate provision for slope drainage, and of bank cutting.
>
> Fire, natural and man-caused, is a second major contributor to accelerated soil-mass movement in some areas. This relates largely to the destruction of the natural mechanical support of soils, often abetted by surface denudation of the soil mantle, opening it to the effects of surface erosion.
>
> Logging affects slope stability mainly through destruction of protective surface vegetation, obstruction of main drainage channels by logging debris, and the progressive loss of mechanical support on the slopes as anchoring root systems decay."

Very little work has been done to establish quantitative cause and effect relationships between mass soil movements and causative factors, including natural characteristics and man's activities in watersheds.

3.3.2 Methods for Quantifying Sediment Loading from Gullies, Streambanks, and Mass Soil Movement

The cause/effect interrelationships of gully erosion, streambank erosion, and mass soil movement have yet to be put into proper perspective. Methods are therefore not available for any given locality and any set of existing or assumed conditions for accurately predicting contributions of sediment loading from these sources. The discussion and general facts presented in the preceding paragraphs will serve as guidelines for estimation of channel erosion and mass soil movement. These guidelines generally apply to two options, presented below, for estimating gully and streambank erosion and mass soil movement at the local/regional level. These options may be used separately or in combination.

3.3.2.1 Estimation from historical local data and research results -

The local history of gully erosion, streambank erosion, and mass soil movement can be obtained by local interview and from existing research results. Research results are available in engineering surveys and basin and project reports. Public agencies which have these results include: Department of Army--Corps of Engineers; Department of the Interior--Bureau of Land Management, Bureau of Mines, Fish and Wildlife Service, and National Park Service; Department of Agriculture--Forest Service and Soil Conservation Service; state departments of water resources; public works authorities; and planning commissions.

3.3.2.2 Estimation from historical topographic data -

Quantification of sediment production from gullies, streambanks, and mass soil movement also can be made through use of aerial photographs. A large area of the United States was photographed from the air about 35 years ago. Many areas have been rephotographed periodically. These aerial photographs provide valuable tools to determine the boundaries and lateral movement of channels during various periods of time and are used extensively in watershed investigations whenever available. The following agencies and organizations have aerial photographs of parts of the United States: Department of the Interior--Geological Survey, Topographic Division; Department of Agriculture--Agriculture Stabilization and Conservation Service, Soil Conservation Service, and Forest Service; Department of Commerce--Coast and Geodetic Survey; Department of the Air Force; National Aeronautics and Space Administration; various state agencies; and commercial aerial survey and mapping firms.

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SECTION 4.0

NUTRIENTS AND ORGANIC MATTER

4.1 INTRODUCTION

Nitrogen and phosphorus are the primary nutrients which are important in agricultural and silvicultural practices. The effect of these nutrients on receiving waters is the increased potential for algal blooms--especially in lakes and reservoirs--thus interfering with many beneficial uses of these waters. Of the two nutrient elements, phosphorus has received greater emphasis because of the available technology to control phosphorus discharges from municipal and industrial sources. Nitrogen is also important as a rate-limiting nutrient for algal growth in some surface waters; however, the nitrogen pathways in plant nutrition are relatively more complex than those of phosphorus. Technology for controlling nitrogen emissions from point sources is not sufficiently advanced to economically justify its adaptation to nonpoint pollutant emissions.

The magnitude of losses of these two nutrient elements from different source activities can, in principle, be calculated by making nutrient budgets of all source inputs and outputs, and specifically determining outputs to surface waters. Methods for estimation of quantities involved in the several parts of a nutrient budget are not well enough developed for use in nutrient loading functions. In addition, the quantities of nutrients that actually reach a stream from a given source are subject to variation depending upon the nature of the intervening terrain. The prediction of nutrient losses from various land uses can in part be accomplished by loading functions which describe the changes of nutrient content in the soil in response to various external variables such as cultural practices, fertilizers, and climatic differences, and which account for soil losses by erosion.

Organic matter from cropland and pastureland carries oxygen-consuming materials that can degrade the quality of receiving waters by stripping its oxygen content, and carries potentially pathogenic microorganisms from livestock wastes and other rural runoff. A loading function for organic matter has been developed based on the organic matter content of soil and sediment yield.

These assumptions are more nearly correct for nitrogen when erosion is moderate to extensive, and are less correct when erosion is slight or when surface runoff is negligible. In the latter cases dissolved forms of nitrogen are the principle nitrogen pollutants. These are transported either to subsurface waters or directly to surface waters in runoff. Functions which describe either of the latter phenomena are not yet available, and the approach to estimating dissolved forms of nitrogen accordingly involves a combination of local or regional experience supplemented by measurements of soluble nitrogen forms in runoff and baseflow.

Nutrient and organic matter loading functions presented in this section are accordingly based on the sediment loading function developed in Section 3.0 entitled "Sediment Loading Functions." It is assumed that the nutrients and organic matter are carried through surface runoff and that most of these are removed with sediment.

Because the currently available data applicable to the entire U.S. may not reflect the local conditions, it is suggested that local data whenever available be used in preference to the general data presented in this section.

4.2 NITROGEN

4.2.1 Introduction

Soil nitrogen is derived from several sources which include geologic weathering, microbial reactions, precipitation, and chemical fixation. Addition of chemical fertilizers and organic residues to soil constitutes man's effort to increase or supplement nitrogen forms which can be readily utilized by plants. Although the cultivated soils contain a large reservoir of total nitrogen in the plowed layer--about 2 to 4 tons/acre--available nitrogen is usually quite small--a few pounds per acre. The significance of this available nitrogen to water pollution is great, however. As much as 95% of total nitrogen in the soil is organically bound and is not readily released in solutions for plant growth. The ammonium ion in soil which is tightly bound to clay or other anionic molecules in soil is also not readily available for plant growth. Nitrate which is not held by soil particles can be readily transported through the soil profile to below the root zone in the absence of an actively growing crop and can eventually join the groundwater pool. The time of migration of groundwater nitrogen to surface waters can extend to several decades depending upon groundwater hydrology relative to surface water hydrology. Significant nitrogen losses to the air occur through volatilization and denitrification processes.

4.2.2 Precipitation

Precipitation contains significant quantities of numerous substances, including nitrogen and phosphorus.[1,2] That precipitation which falls on surface waters carries with it a load which becomes a part of the total pollutant load. The direct contribution via precipitation is negligible for surface streams, and may be substantial for lakes or still-standing waters--as much as 50% of the total nutrient input.[2] Contributions of precipitation-borne nutrients to surface waters via overland runoff will vary in proportion to both precipitation and runoff. The simplest approach is to assume that overland runoff carries with it, without loss to the soil, the nitrogen and phosphorus load which it contained when it reached the earth. Overland runoff is seldom very direct except in high intensity/high quantity storm events or in certain types of snowmelt, and rainfall entrained nutrients will in most runoff events be exposed to mineral and organic matter in the soils. Phosphorus and nitrogen should be somewhat attenuated by exposure to the soil.

That fraction of precipitation-borne phosphorus carried in precipitation which does not discharge to streams via overland runoff becomes a part of the inventory of phosphorus in the soil, and becomes relatively immobile in the surface layers of soil. The surface-sorbed phosphorus becomes a nonpoint pollutant when it is discharged to streams on eroded sediment.

That fraction of precipitation-borne nitrogen which is not immediately carried off in overland runoff also enters the soil compartment where it continues its participation in the complex nitrogen cycle: some stays in the root zone, and may be completely utilized by plant life; some moves below the root zone, and thus becomes involved in a very ill-defined physical-chemical-biological-hydrologic system; some of that which stays in the root zone is a candidate for transport, later, to surface streams in overland runoff.

Since only a small fraction of precipitation incident on land enters surface waters by overland runoff, the great majority of precipitation-borne phosphorus and nitrogen is deposited on the land and becomes a part of its continually changing inventory of nutrients. The present discussion is concerned with estimation of the fractions of the precipitation-borne nutrients transported directly, via overland runoff, to surface waters. An analysis of "national average" data is instructive.

Annual average precipitation is 76 cm (30 in.). Annual average runoff via all processes is 25 cm (10 in.). The fraction of runoff occurring by the overland varies widely; for purposes of discussion 20% of total runoff will suffice. Average annual overland runoff is thus 5 cm (2 in.), or about 7% of precipitation.

Reported deposition rates of nitrogen and phosphorus in rainfall range from about 5 to 10 kg/ha/year (4.4 to 8.9 lb/acre/year) for nitrogen, and reportedly average 0.05 to 0.06 kg/ha/year (0.045 to 0.055 lb/acre/year) for phosphorus.[1,2]

Seven percent of the precipitation-borne phosphorus and nitrogen might thus be carried directly to surface waters, if no absorption on soil is assumed. Nonattenuated yield rates, for stream deposition, national average basis, would accordingly be 0.35 to 0.7 kg/ha (0.31 to 0.62 lb/acre) of nitrogen, and 0.0035 to 0.004 kg/ha (0.0031 to 0.0036 lb/acre) of phosphorus. If one assumes that phosphorus is 50% attenuated and nitrogen 25% attenuated, the net yields become 0.28 to 0.53 kg/ha (0.25 to 0.47 lb/acre) of nitrogen, and 0.0018 to 0.002 kg/ha (0.0016 to 0.0018 lb/acre) of phosphorus.

If one translates the above data into in-stream concentrations (assuming no in-stream transformations), the results are 0.11 to 0.21 ppm nitrogen, and 0.7 to 0.8 ppb of phosphorus. Comparison of these concentrations with the national benchmark station data summarized in Figures 12-3 and 12-4 reveals the perhaps fortuitous comparison that nitrogen concentrations estimated from precipitation are the same as what appears to be an average for nationally observed concentrations in locations relatively unaffected by man. The above estimated concentrations for phosphorus are lower than benchmark station concentrations (0.7 to 0.8 ppb vs 10 to 200 ppb of total phosphorus). This comparison indicates that the load of precipitation-borne phosphorus is a small fraction of the phosphorus nonpoint contribution to surface streams, but that nitrogen contributions are a significant part of the in-stream burden of available forms of nitrogen (particularly nitrate).

A comparison of nutrient contribution from precipitation with that from croplands reveals that, on a national basis, the eroded soil from croplands yields about 20 kg/ha/year (18 lb/acre/year) of total nitrogen.[3] Assuming a 7% value for the available fraction in total nitrogen, the load of available nitrogen from cropland becomes 1.42 kg/ha/year (1.26 lb/acre/year). This value compares with 0.28 to 0.53 kg/ha/year (0.25 to 0.47 lb/acre/year) of available nitrogen in precipitation. Since the cropland nitrogen loading function does not account for precipitation loads, the total contribution to a stream should include both these sources. The total load of "available" nitrogen thus is about 1.8 kg/ha/year (1.6 lb/acre/year), on a national average basis, from cropland.

Although available nitrogen is extremely significant in the enrichment of stream nutrition, the role of the remainder of the total nitrogen carried on eroded sediment is also substantial. Since streams are dynamic in nature, there is a continuous mineralization of soil nitrogen by the microorganisms in the bottom sediment which is supplied with oxygen from both stream reaeration processes and photosynthetic processes. Thus, the delayed release of available nitrogen to the aquatic systems can be as significant as the available nitrogen in precipitation and eroded soil. For example, in-stream nitrogen burdens averaged over the Missouri River basin translate to an average yield of about 3 lb/acre/year[4/] of nitrate-nitrogen, which is two to three times the delivered rate from nonpoint sources and precipitation.

Nitrogen loading from precipitation should be added to that from surface erosion processes to obtain the total load. Since the load for phosphorus from precipitation is small, the phosphorus loading function does not include the contribution from precipitation.

4.2.3 Nitrogen Loading Function

While the complex interactions in soil, air, water, and plants are reasonably well understood, methods for quantifying movements within the system are still in the research stage. Methods which are suitable for general use oversimplify the problem, must be used with discretion, and may be quite inadequate in certain cases. In particular, it is not presently possible to describe leaching processes for soluble forms of nitrogen. The nitrogen loading function is made up of two sources: (a) erosion; and (b) precipitation. Total nitrogen loading is obtained by adding the yields from both sources. The loading functions exclude leaching losses, and predict the amount of total nitrogen that is released to surface waters by runoff and erosion. The nitrogen in precipitation is mostly in available form.

Nitrogen loading function for erosion loss is:

$$Y(NT)_E = a \cdot Y(S)_E \cdot C_S(NT) \cdot r_N \qquad (4\text{-}1)$$

where $Y(NT)_E$ = total nitrogen loading from erosion, kg/year (lb/year)

a = dimensional constant (10 metric, 20 English)

$C_S(NT)$ = total nitrogen concentration in soil, g/100 g

$Y(S)_E$ = sediment loading from surface erosion, MT/year (tons/year)

r_N = nitrogen enrichment ratio

Available nitrogen can be obtained by using a fraction f_N which is the ratio of available N to total N in sediment. Thus, the available nitrogen in sediment is

$$Y(NA)_E = Y(NT)_E \cdot f_N \tag{4-2}$$

Nitrogen loading function for precipitation is

$$Y(N)_{Pr} = A \cdot \frac{Q(OR)}{Q(Pr)} \cdot N_{Pr} \cdot b \tag{4-3}$$

where $Y(N)_{Pr}$ = stream nitrogen load from precipitation, kg/year (lb/year)

A = area, ha (acres)

$Q(OR)$ = overland flow from precipitation, cm/year (in/year)

$Q(Pr)$ = total amount of precipitation, cm/year (in/year)

N_{Pr} = nitrogen load in precipitation, kg/ha/year (lb/acre/year)

b = attenuation factor

Almost all of $Y(N)_{Pr}$ will be in the available form so that the total available nitrogen from both erosion and precipitation may be obtained by adding Eqs. (4-2) and (4-3). Thus,

$$Y(NA) = Y(NT)_E \cdot f_N + Y(N)_{Pr} \tag{4-4}$$

4.2.4 Evaluation of Parameters in the Nitrogen Loading Function

The value of $Y(S)_E$ can be evaluated from the sediment loading function presented in Section 3.0 "Sediment Loading Functions." The value of the enrichment ratio r_N is variable according to the soil texture and cultural treatment. Viets[5] presented the values of r_N using data from small experimental plots (see Table 4-1). Hagin and Amberger,[6] as well as Stoltenberg and White,[7] have proposed an r_N value of 2.0. Massey et al.[8] estimated the value of r_N as 2.7. Because of wide variations in the properties of erodible soil, a single value of r_N is not probable; the values reported range from less than 2.0 to greater than 4.0, and an appropriate value should be selected for a specific location from local knowledgeable sources such as the State Agricultural Experiment Stations.

Table 4-1. NUTRIENT AND SEDIMENT LOSSES[5]

Source	Total loss (kg/ha)			Enrichment ratio, r	
	Soil	N	P	N	P
Check	29,100	74.5	75.8	3.88	1.59
Rye winter cover crop	13,160	38.9	37.7	4.08	1.56
Manure (45 MT/ha)	18,390	52.8	44.3	4.28	1.47
Rye and manure (45 MT/ha)	8,130	21.5	19.6	3.35	1.47

Nutrient losses from forest soils are typically very low. Kilmer[9] cited several authors toshow that nutrient losses from forestlands are insignificant. Clear-cutting and buring of forest areas accelerate the release of nutrients (Table 4-2). The erosion-based loading function for nitrogen losses will obviously yield inaccurate estimates of nitrogen losses from sources such as forests and pastureland which have good cover and from which soil loss by erosion is negligible. For this case, it is approrpiate to use Eq. 4-1 only with substantial reservations, and the user is advised to use case study data which appear to best represent his area of concern. This latter approach requires that the user define the mechanisms which describe his situation, i.e., the relative contributions from erosion, leaching, and surface transport in runoff, and discharge via groundwater/subsurface return mechanisms.

Table 4-2. EFFECT OF CLEAR-CUTTING AND FERTILIZATION ON NUTRIENT OUTPUT IN DOUGLAS FIR FORESTS[a]

Treatment	N (kg/ha)	P (kg/ha)
Control	0.21	0.01
Clear-cut	0.39	0.05
Fertilized (200 lb/acre) urea	0.28	0.03
Ammonium sulfate	0.43	0.07

---

[a] Source: Cole and Gessel (1965) cited by Kilmer.[9]

Nitrogen losses by leaching are also negligible from actively growing grassland. However, losses from legume grass mixtures can be high. Lysimeter studies by Low and Armitage (page 7 of Ref. 9) showed that clover produced about 10 times as much N loss in drainage as that in actively growing grass; however, the loss was 100 times as much when the clover crop died.

Runoff losses of nitrogen from grass sod plots ranged from 2% of applied nitrogen when soil moisture was 12.5%, to 14% at 25.8% moisture.[10] Timmons et al.[11] determined N and P losses in runoff solution and sediment in Minnesota. Their results indicate that leaching losses from a hay rotation could contribute to substantial N and P losses in solution.

The value of $C_S(NT)$ in the plowed layer of soil is variable from location to location and from time to time. Estimates of native soil nitrogen in the U.S. indicate a range between 0.02 and 0.4%.[12] Parker et al. published a map in 1946 showing the nitrogen content in the top 1-ft layer in the U.S.[13] (see Figure 4-1). Data in Figure 4-1 should be viewed in general terms; for specific sites, local sources such as SAES and SCS Soil Surveys should be consulted.

Precipitation also contributes to the soil nitrogen. Atmospheric nitrogen extracted by soil microbes becomes incorporated into soil organic matter; animal manures, crop residues, and other wastes contribute significant amounts of nitrogen to the soil. Jenny[12] expressed the nitrogen content of the soil in terms of temperature, T, and a humidity factor, H. Jenny's equation is:

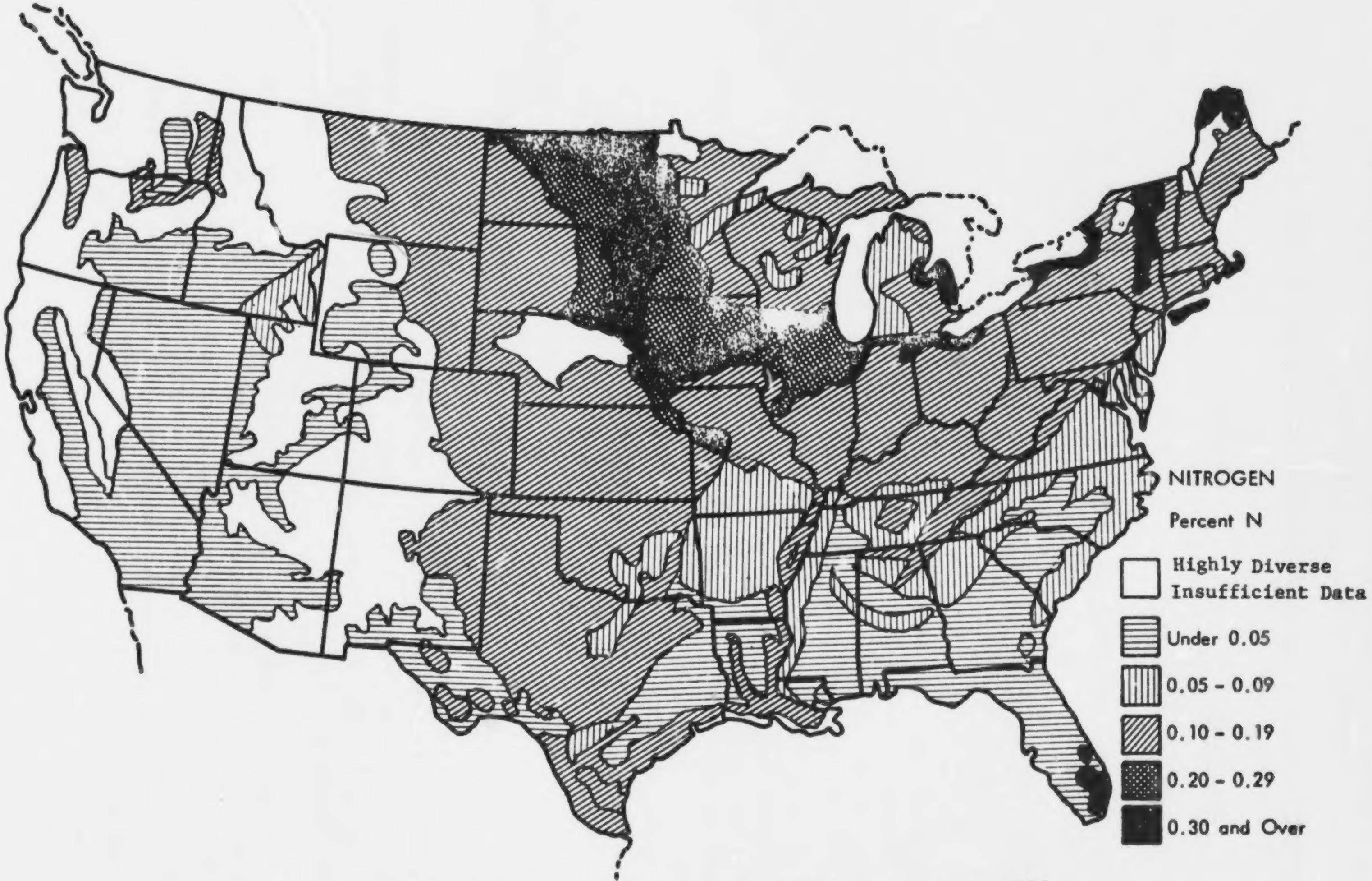
NITROGEN
Percent N
☐ Highly Diverse Insufficient Data
▤ Under 0.05
▥ 0.05 - 0.09
▨ 0.10 - 0.19
▩ 0.20 - 0.29
■ 0.30 and Over

Figure 4-1. Percent nitrogen (N) in surface foot of soil.[13]

$$C_S(NT) = 0.55\ e^{-0.08T}\ (1 - e^{-0.005H}) \tag{4-5}$$

$$H = \frac{P}{(1 - \frac{RH}{100})\ SVP_t} \tag{4-6}$$

where P = precipitation, mm/year

$C_S(NT)$ = concentration of soil nitrogen, g/100 g

T = annual average temperature, °C

RH = relative humidity, %

SVP_t = saturated vapor pressure at given temperature, mm of Hg

Equation (4-7) shows the relation between SVP_t and T.*

$$SVP_t = 10^{[9.2992 - 2360/(273 + T)]} \tag{4-7}$$

The solution of Eq. (4-5) is shown graphically in Figure 4-2. The value of humidity factor, H, can be determined from Eqs. (4-6) and (4-7). A nomograph solution of H is shown in Figure 4-3. For given values of precipitation, relative humidity and temperature, the value of H can be quickly and accurately established from Figure 4-3. For example, given P_1 = 500 mm/year (19.7 in/year), RH_1 = 60%, and T_1 = 5°C (41°F), the value of H factor can be determined as follows: using a straight-edge ruler, align P_1 and RH_1 to intersect on the index line at "a" as shown on the inset of Figure 4-3. Align "a" with T_1 on the temperature scale to intersect the H scale. The result on the H scale is 194.

Data in Figure 4-1 may be used as a check on current data. Equations (4-6) and (4-7) may be used to calculate nitrogen content of soil more precisely if necessary data are available for using these equations. Again data from State Agricultural Experiment Stations, and SCS Soil Surveys are much more dependable than the above sources and should be consulted whenever possible.

The fraction of available nitrogen to total nitrogen in soil, f_N is variable, depending upon many factors such as soil characteristics, degree of mineralization, and organic matter content. The most important forms of available nitrogen are NH_4^+, NO_3^-, and certain simple organic compounds containing free amide or amino groups. Nitrate is only a minor source of available nitrogen in soil.

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* Modified from Gladstone, S., Elements of Physical Chemistry, D. Van Nostrand Company, Inc., New York, New York (1946).

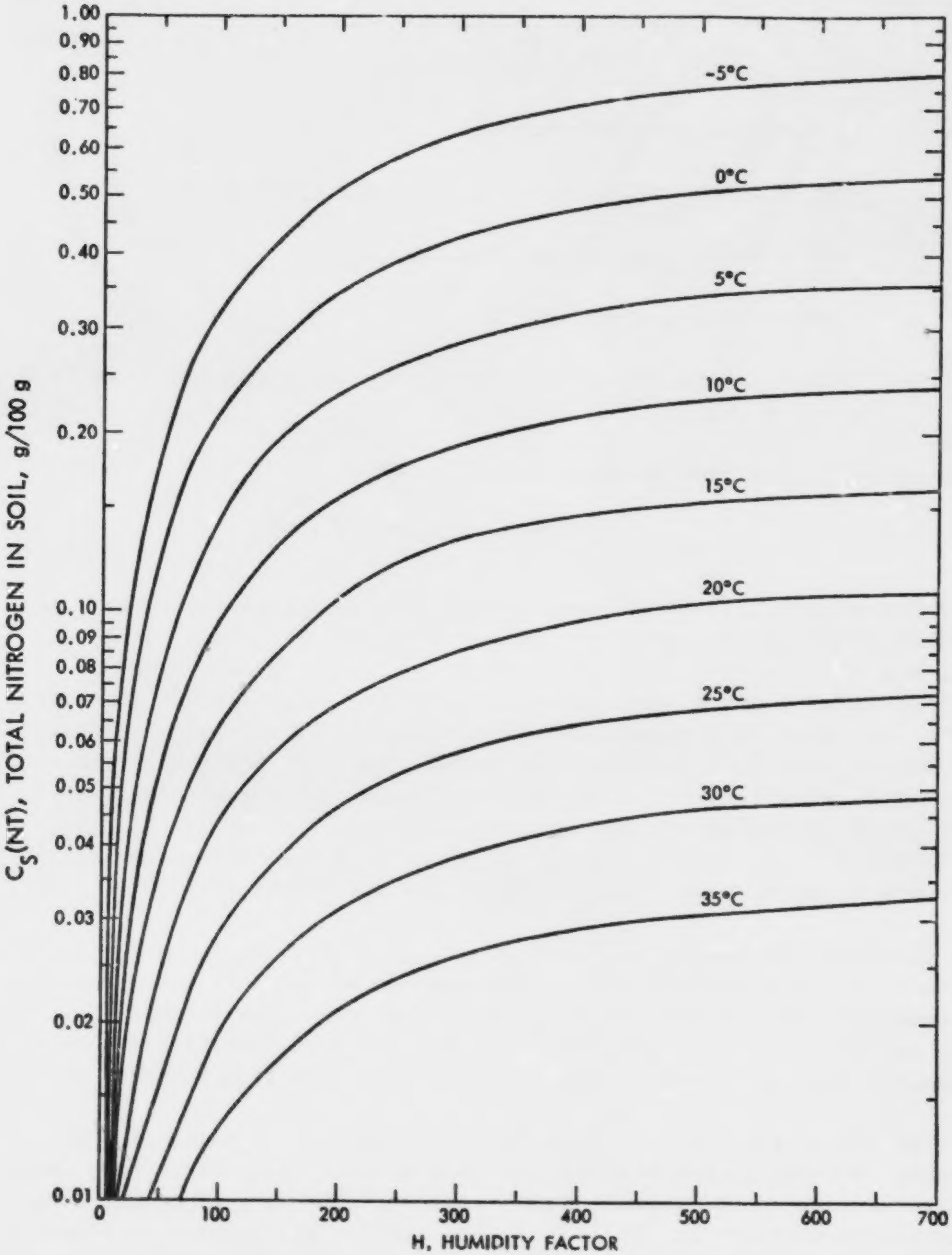
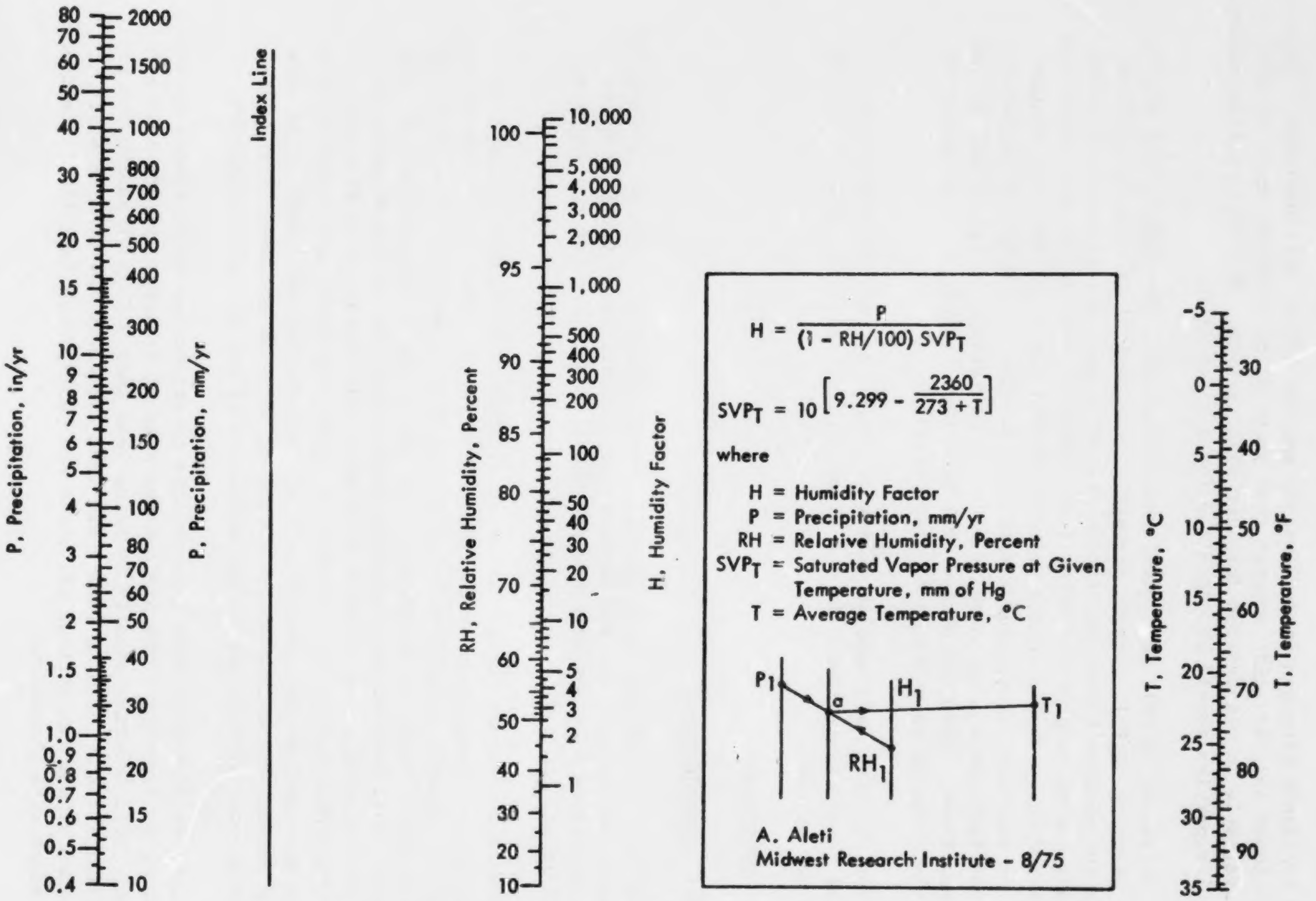


Figure 4-2. Soil nitrogen vs humidity factor and temperature



$$H = \frac{P}{(1 - RH/100)\ SVP_T}$$

$$SVP_T = 10^{\left[9.299 - \frac{2360}{273 + T}\right]}$$

where

H = Humidity Factor
P = Precipitation, mm/yr
RH = Relative Humidity, Percent
SVP_T = Saturated Vapor Pressure at Given Temperature, mm of Hg
T = Average Temperature, °C

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Midwest Research Institute - 8/75

Figure 4-3. Nomograph for humidity factor, H

The available nitrogen in soil rarely exceeds 15% of totalnitrogen. Data from Lopez and Galvez[14] suggest that about 8% of total nitrogen in soil is available in mineralized form for plant growth. For more precise values, local expertise should be consulted for a given area.

The values of Q(OR) and Q(Pr) may be obtained from local data sources. The value of Q(Pr) (annual average precipitation) is usually obtained from the weather bureau statistics for the area. The value of overland runoff can be roughly estimated from stream flow data. A user unfamiliar with hydrology should consult with qualified personnel in state conservation services, agricultural extension service, the Corps of Engineers, or the Agricultural Research Service for assistance in interpretation of stream flows. These resources will also have historical information on overland runoff in relation to precipitation.

Values of N_{Pr} are usually available from measurements made in the local research stations. In the absence of actual data, data in Figure 4-4 may be used.

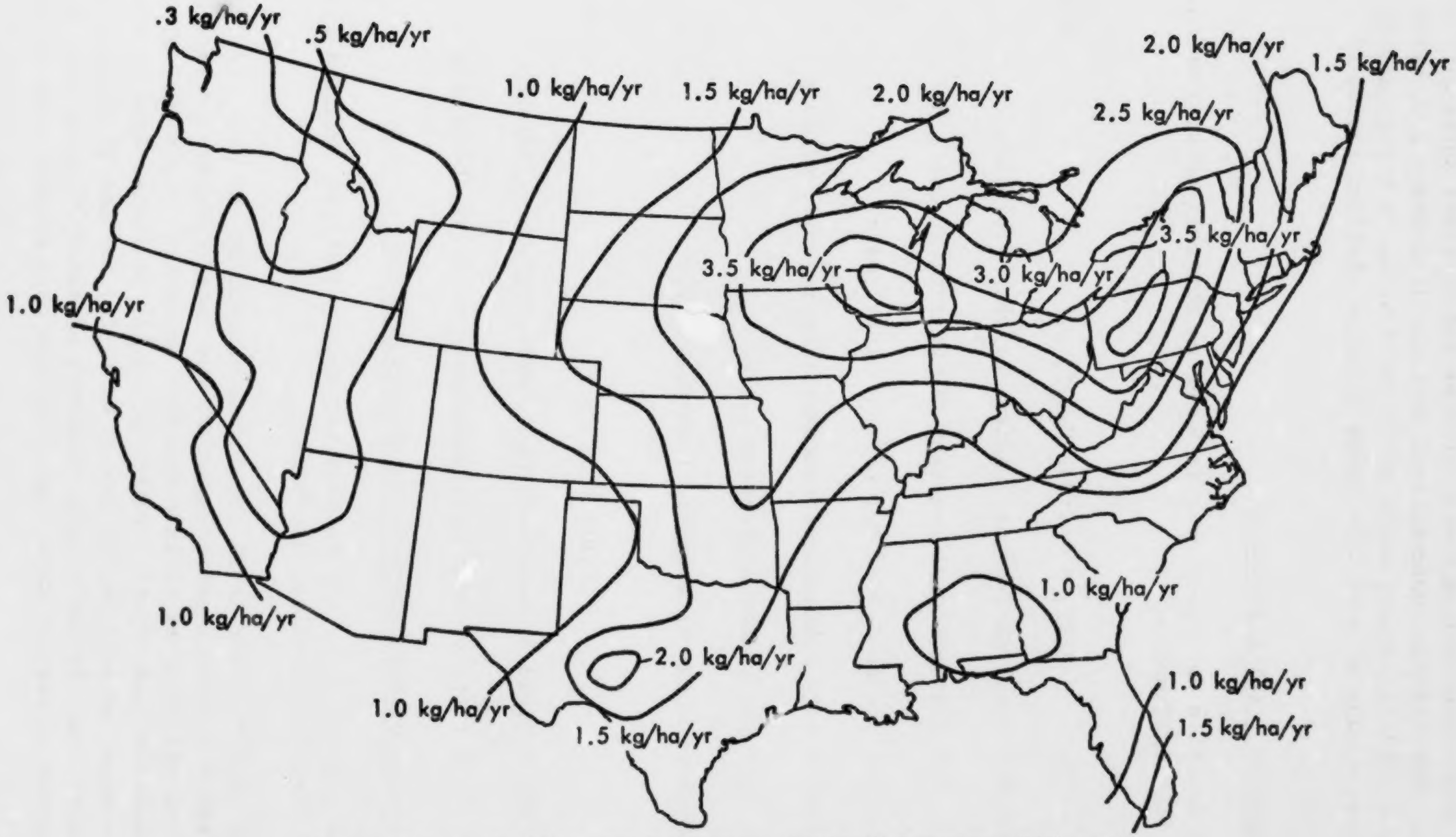
4.3 PHOSPHORUS

4.3.1 Introduction

Phosphorus occurs naturally in soil from weathering of primary phosphorus-bearing minerals in the parent material. Additions of plant residues and fertilizers by man enhances the phosphorus content of the surface soil layer.

Phosphorus in soils occurs either as organic or inorganic phosphorus. The relative proportion of the phosphorus in these two categories varies widely. Organic phosphorus is generally high in surface soils where organic matter tends to accumulate. Inorganic forms are prevalent in subsoils. Soil phosphorus is readily immobilized due to its affinity to certain minerals. In strongly acid soils the formation of iron and aluminum phosphates, and in alkaline soils, the formation of tricalcium phosphate reduces the availability of soil phosphorus. Once it is lost to a stream, the nature of phosphorus existing in sediment or in solution becomes significant in the nutrition of aquatic microorganisms.

Phosphorus transport from a given site to stream can occur either by erosion or by leaching. The predominant mode of transport is via soil erosion. Soil solution usually contains less than 0.1 µg of phosphorus per milliliter; the leaching losses are thus extremely low even in well-drained soils. Exceptions are sands and peats which have little tendency to react with phosphorus.


.3 kg/ha/yr
.5 kg/ha/yr
1.0 kg/ha/yr
1.5 kg/ha/yr
2.0 kg/ha/yr
2.0 kg/ha/yr
1.5 kg/ha/yr
2.5 kg/ha/yr
3.5 kg/ha/yr
3.5 kg/ha/yr
3.0 kg/ha/yr
1.0 kg/ha/yr
1.0 kg/ha/yr
1.0 kg/ha/yr
2.0 kg/ha/yr
1.0 kg/ha/yr
1.5 kg/ha/yr
1.0 kg/ha/yr
1.5 kg/ha/yr

Source: Personal Communication, Jay H. Cravens, Regional Forester, USDA - FS, Eastern Region, Milwaukee, Wisconsin, August 1974.

Figure 4-4. Nitrogen (NH_4-N and NO_3-N) in precipitation

Phosphorus losses from well managed pastures and forested soils are usually low. For example, unfertilized pastures lost about 0.03 kg/ha of P during a 6-month period, while addition of 45 kg of P per hectare resulted in an escape of only 0.04 kg/ha during a similiar period of time.[9]

4.3.2 Phosphorus Loading Function

The loading function for phosphorus is based on the soil erosion mechanism. The loading function is:

$$Y(PT) = a \cdot Y(S)_E \cdot C_S(PT) \cdot r_P \qquad (4\text{-}8)$$

where $Y(PT)$ = total phosphorus loading, kg/year (lb/year)

a = a dimensional constant (10 metric, 20 English)

$Y(S)_E$ = sediment loading, MT/year (tons/year)

$C_S(PT)$ = total phosphorus concentration in soil, g/100 g

r_P = phosphorus enrichment ratio

Available phosphorus may be computed from Eq. (4-9):

$$Y(PA) = Y(PT) \cdot f_P \qquad (4\text{-}9)$$

where $Y(PA)$ = yield of available phosphorus, kg/year (lb/year)

f_P = ratio of available phosphorus to total phosphorus

4.3.3 Evaluation of Parameters in Phosphorus Loading Function

Sediment loading, $Y(S)_E$, may be obtained from procedures outlined in Section 3.0 "Sediment Loading Functions."

The value of $C_S(PT)$, the total phosphorus content of the soil, is variable. For any given location, current and local data are preferred to generalized values given in this report. No central repository of current nationwide data exists. Parker et al.[13] published data on the phosphorus content of soil in the top 30 cm (1 ft) for the 48 states, as shown in Figure 4-5. Parker's data, although obtained 30 years ago, will serve as a check on current data. Soil surveys periodically made by the

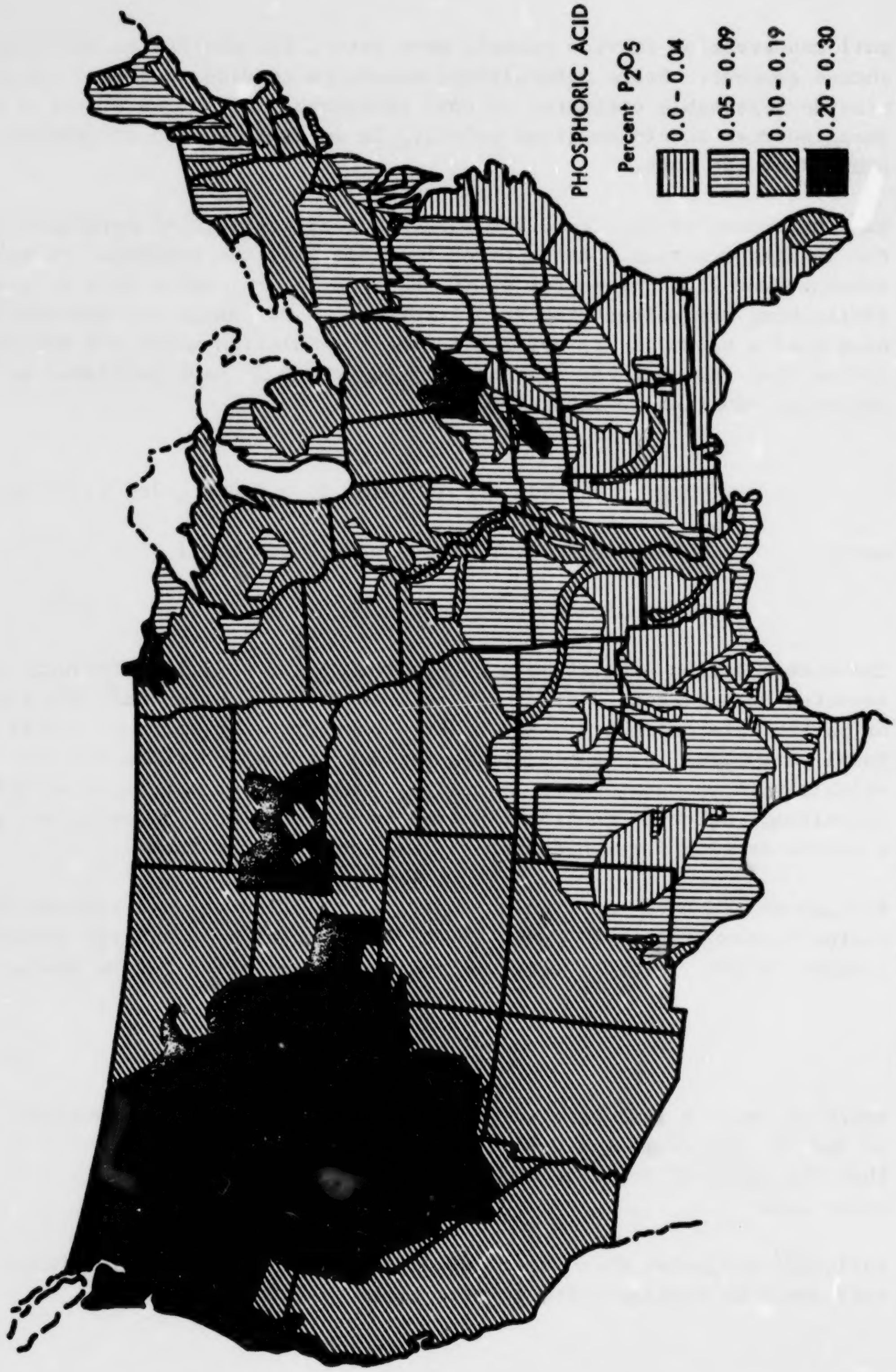

PHOSPHORIC ACID
Percent P_2O_5
0.0 – 0.04
0.05 – 0.09
0.10 – 0.19
0.20 – 0.30

Figure 4-5. Phosphorus content in the top 1 ft of soil.13/

Soil Conservation Service contain more recent information on soil phosphorus content. State agricultural extension service personnel can also provide reasonable estimates of soil phosphorus content in a given area. These sources should be given priority in determining the phosphorus content of the soil.

The enrichment ratio, r_p, has been the least researched parameter in the loading function. As reported in Table 4-1, the reported r_p values average about 1.5. Massey et al.[8] obtained an r_p value of 3.4, and Stoltenberg and White[7] reported a value of 2.0. Hagin and Amberger[6] have used a value of r_p of 2.5 in their simulation model for nutrient losses from agricultural sources. Massey et al.[8] have developed an empirical equation to determine r_p :

$$\log r_p = 0.319 + 0.25\ (-\log X) + 0.098\ (-\log Y) \qquad (4\text{-}10)$$

where X = sediment loss, tons/acre-in of runoff

Y = sediment loss, tons/acre

The determination of available phosphorus in the soil is difficult. Most reported data fail to distinguish between soluble phosphorus, adsorbed or particulate phosphorus, and organic phosphorus in sediment runoff. Total phosphorus is a somewhat meaningless parameter, since only the soluble orthophosphate form is readily available for uptake by aquatic organisms. Other forms of phosphorus in sediment can, however, act as a source or sink for subsequent release in available form.

Schuman et al. have reported an empirical relation between sediment phosphorus (concentration in ppm, $C_S(PT)$) and soluble phosphorus (concentration in ppm, $C_Q(P)$) for Iowa soils. The relation may be stated as:

$$C_Q(P) = a + b \cdot C_S(PT) \qquad (4\text{-}11)$$

where a and b are regression coefficients. The reported values of a and b are 0.018 and 0.047, respectively.[15] Equation (4-11) shows that the ratio of solution phosphorus to sediment phosphorus is just under 1:20.

Taylor[16] suggested that about 10% of the total phosphorus in eroded soil would be available for aquatic plant growth.

4.4 ORGANIC MATTER

4.4.1 Organic Matter Loading Function

The loading function is:

$$Y(OM)_E = a \cdot C_S(OM) \cdot Y(S)_E \cdot r_{OM} \qquad (4\text{-}12)$$

where $Y(OM)_E$ = organic loading, kg/year (lb/year)

a = a dimensional constant (10 metric, 20 English)

$C_S(OM)$ = organic matter concentration of soil, g/100 g

$Y(S)_E$ = sediment loading, MT/year (tons/year)

r_{OM} = enrichment ratio for organic matter in eroded soil

4.4.2 Evaluation of Parameters in the Organic Matter Loading Function

The value of $Y(S)_E$ can be obtained from procedures discussed in Section 3.0. The value of $C_S(OM)$ should be obtained preferably from current or historical data for a given area, e.g., from the extension service. For approximate values, $C_S(OM)$ may be taken as equal to $20 \times C_S(NT)$, where $C_S(NT)$ is the total nitrogen concentration in the soil.[17]

The value of r_{OM} , the enrichment ratio, is more difficult to assess due to lack of research data. Values of r_{OM} are in the range of 1 to 5. The enrichment ratio for sandy soils will be high. Conversely, the enrichment ratio will be low when the mineral fraction of the soil is finely divided and highly erodible. The user should consult with local soil experts and should use local data when available.

4.5 ACCURACY OF LOADING FUNCTIONS

The accuracy of predicting loads using the loading functions presented in the preceding sections depends, to a large extent, on the availability of reasonably accurate data for evaluating the various parameters in the functions. For example, the nitrogen loading function is composed of several parameters each of which is in turn a function of several other variables. In addition, several options are available to the user to develop the parameter values from his own sources of information which may alter the prediction accuracy. However, if the used values reflect the long-term average rather than a specific year, and if reasonably large areas are used such as large watersheds (> 100 sq miles) rather than individual plots or small watersheds, the expected accuracy can be reasonably estimated. Using the reasoning that the error in individual parameters will tend to cumulate to a larger error, the expected ranges of predicted values for given "true" or estimated values of load are presented in Table 4-3.

Table 4-3. PROBABLE RANGE OF LOADING VALUES FOR NUTRIENTS AND ORGANIC MATTER

Loading function	Estimated value (kg/ha/year)	Probable range (kg/ha/year)
Total N sediment[a]	1	0.1-10
Total N sediment	10	5-20
Total N sediment	50	30-75
Total N precipitation[b]	0.3	0.1-0.6
Total P[c]	1.0	0.5-3.0
Total P	5.0	2-10
Total P	10.0	5-20
Organic matter	10.0	5-20
Organic matter	100	50-200

---

[a] Available N in sediment will range from 3 to 8% of total N.

[b] Available N is equal to total N in precipitation.

[c] Available P in sediment will range from 5 to 10% of total P.

4.6 EXAMPLE OF LOADING COMPUTATION

The watershed given in Section 3.0, entitled "Sediment Loading Functions," for Parke County in Indiana will be used to illustrate the methodology presented in this section for computing the loads. It is required to compute available nitrogen, available phosphorus, and organic matter loading for the given area for the following conditions:

Average daily loading;
Maximum daily loading during a 30 consecutive day period; and
Minimum daily loading during a 30 consecutive day period.

The following data, plus soil loss data, are required:

Soil nitrogen content.
Soil phosphorus content.

The preferred source of these data is local records. Jenny's equation (Eq. 4-5) and Figure 4-5 are alternate sources from which general values may be estimated.

4.6.1 Nitrogen Loading

Using the following data, soil nitrogen content is calculated:

Average annual temperature = 10°C
Average annual precipitation = 96.5 cm
Average annual relative humidity = 70%

Using the nomograph given in Figure 4-3, the value of H factor was determined to be 350. From Figure 4-2, and using H = 350 and T = 10°C, the value of $C_S(NT)$, the soil nitrogen content was estimated to be 0.204% or 0.204 g/100 g. Assume that 6% of total nitrogen is available, and r_N is 2.0. Using Eqs. (4-1) and (4-2),

$$\begin{aligned} Y(NA)_E &= 20 \cdot Y(S)_E \cdot 0.204 \cdot 2.0 \cdot 0.06 \qquad (4\text{-}13) \\ &= 0.49 \cdot Y(S)_E \end{aligned}$$

The values of areal sediment yield as given in the example in Section 3.0, entitled "Sediment Loading Functions," are shown below in Table 4-4.

Table 4-4. SEDIMENT YIELD IN EXAMPLE

	Sediment yield (tons/day)		
Land use	Daily average	Maximum 30 days	Minimum 30 days
Cropland	2.88	9.36	0.72
Pasture	0.33	0.84	0.09
Woodland	0.39	0.95	0.09
Total	3.60	11.15	0.90

The nitrogen loadings are shown in Table 4-5 using the data in Table 4-4 and Eq. (4-13).

Table 4-5. AVAILABLE NITROGEN LOADING, $Y(NA)_E$, IN EXAMPLE

	Nitrogen loading (lb/day)		
Land use	Daily average	Maximum 30 days	Minimum 30 days
Cropland	1.41	4.59	0.35
Pasture	0.16	0.41	0.04
Woodland	0.19	0.47	0.04
Total	1.76	5.47	0.43

4.6.2 Phosphorus Loading

Assume $C_S(PT) = 0.255$ g/100 g for the area, 10% of $C_S(PT)$ is available phosphorus, $C_S(PA)$; and r_P is 1.5, and using Eq. (4-8);

$$Y(PA)_E = 20 \cdot Y(S)_E \cdot 0.255 \cdot 1.5 \cdot 0.10 \qquad (4\text{-}14)$$

$$= 0.765\ Y(S)_E$$

Phosphorus loadings computed from Table 4-2 and Eq. (4-8) are shown in Table 4-6.

Table 4-6. AVAILABLE PHOSPHORUS LOADING, $Y(PA)_E$, IN EXAMPLE

	Phosphorus loading (lb/day)		
Land use	Daily average	Maximum 30 days	Minimum 30 days
Cropland	2.20	7.16	0.55
Pasture	0.25	0.64	0.07
Woodland	0.30	0.73	0.07
Total	2.75	8.53	0.69

4.6.3 Organic Matter Loading

Using Eq. (4-12), data for $C_S(OM)$, $Y(S)_E$, r_{OM} are needed.

Assume that the value of $C_S(OM)/C_S(NT)$ equals 20 and $r_{OM} = 2.5$,

$$Y(OM)_E = 20 \cdot 2.5 \cdot Y(S)_E \cdot 20 \cdot C_S(NT)$$

$$= 1000 \cdot C_S(NT) \cdot Y(S)_E$$

Using $C_S(NT) = 0.2\%$,

$$Y(OM)_E = 200 \cdot Y(S)_E \tag{4-15}$$

The values of organic loading are computed from Eq. (4-15) and presented in Table 4-7.

Table 4-7. ORGANIC MATTER LOADINGS IN EXAMPLE

	Organic matter loading (lb/day)		
Land use	Daily average	Maximum 30 days	Minimum 30 days
Cropland	576	1,872	144
Pasture	66	168	18
Woodland	78	190	18
Total	720	2,230	180

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SECTION 5.0

PESTICIDES

5.1 INTRODUCTION

Pesticides dissipate by several mechanisms: chemical degradation (hydrolysis; oxidation); biochemical degradation by soil organisms and enzymatic systems; volatilization; absorption in plant or animal tissue, with or without decomposition; leaching into subsurface soils, possibly into subsurface aquifers; and overland transport in surface runoff and eroded sediment. Losses by leaching processes and by overland transport mechanisms are relevant to contamination of water. Pesticide loading functions must relate mechanisms for these processes to quantities deposited in surface waters. The total load of pesticide deposited in surface waters equals the sum of (a) pesticide transported overland, and (b) pesticide transported by subsurface processes (leaching, soil moisture movement, drainage water movement, groundwater discharge to surface). Soluble pesticides are subject to leaching into subsurface soils and waters, solubilize in overland runoff water, and are also transported overland as sediment-bound material. Insoluble pesticides are transported to surface waters primarily by being carried on eroded sediment.

Data requirements for a precise pesticide loading function are as follows:

1. Quantity of pesticide in the source, expressed as some suitable function of the area, volume, or mass of the source, e.g., concentration in erodible soil layer; concentration and concentration distribution in leachable soil profile. The quantity information should be time specific, i.e., detail source quantities/concentrations as a function of time elapsed since application, season, etc. Since most pesticides degrade, rates of degradation are needed to enable calculation of source quantities as a function of time.

2. Quantitative data on overland runoff, by month, season, and year.

3. Quantitative data on sediment transported from the source and delivered to surface streams.

4. Quantitative data on percolation; seepage; drainage water inventories and movement; and groundwater inventories and movement.

5. Accurate coefficients, rate constants, etc., for desorption--solubilization--leach transport of pesticides through soil columns, of numerous possible soil types.

6. Information on miscellaneous modes of pesticide movement or deposition such as by volatilization, by removal in harvested vegetative matter, and direct deposition in surface waters.

Some of the required data is not available or is unknown, and other data are known or available in varying accuracy and degree of coverage of source situations.

The approach to estimation of contamination of water by pesticides will therefore vary in response to a combination of three factors: (a) degree of required accuracy; (b) availability of data; and (c) capabilities of predictive functions. The greatest impediment is lack of data. Loading functions and approaches to estimation of pesticide pollution are presented, in succeeding sections, for three source conditions. These are:

Case 1 - Water Insoluble Pesticides: Average concentrations of pesticide in soils known. Pesticide load is calculated as a function of sediment loads. Approach most applicable to large areas. Use limited to annual average loads.

Case 2 - Water Insoluble Pesticides: Pesticide use history accurately known, soil analytical data current and extensive, pesticide properties (especially rates of disappearance) well known. Calculate load as function of sediment loss; useful for annual average, 30-day maximum, 30-day minimum.

Case 3 - Water Soluble and Water Insoluble Pesticides: Concentrations in runoff waters known, runoff water flows known (stream source approach). Calculate loads at watershed discharge points, distribute load over watershed land uses in proportion to known or probable pesticide use.

These approaches or options do not treat pesticides discharged to groundwater aquifers and subsurface drainage. The latter can be treated if drainage discharge flows are known, together with concentrations of pesticides in the drainage. Pesticide contamination in groundwater aquifers is presently a research area.

These approaches do not preclude the use, in special or highly documented situations, of research models or approaches which are being locally developed by research scientists.

5.2 PESTICIDE LOADING FUNCTIONS

5.2.1 Case 1: Insoluble Pesticides, Average Soil Concentrations Known

The loading function is:

$$Y(HIF)^{*} = Y(S)_E \cdot C(HIF) \cdot r_{HIF} \cdot 10^{-6} \qquad (5\text{-}1)$$

where $Y(HIF)$ = pesticide yield for source, kg/day (lb/day)

$Y(S)_E$ = sediment yield, kg/day (lb/day)

$C(HIF)$ = concentration of pesticide in soil (ppm)

r_{HIF} = enrichment ratio

Sediment yields, $Y(S)_E$, for the source are calculated by methods presented in Section 3.0.

Pesticide concentrations in cropland soils throughout the United States are being monitored by the Environmental Protection Agency, Office of Pesticide Programs, in the National Pesticide Monitoring Program (NPMP). The data base emphasizes persistent pesticides, and does not cover soils outside croplands. It therefore is a limited source of historical data, and should be used accordingly. Results for 35 pesticides are summarized, for FY 1969 in Pesticides Monitoring Journal, 6(3):194-228, 1972. (This article is reproduced in Appendix F.) The FY 1969 data cover cropland soils in 43 states and noncropland soils in 11 states.

The NPMP FY 1969 data may be used, with considerable discretion, as C(HIF) values in Eq. (5-1). The "range of detected residues" will serve as input for calculation, with Eq. (5-1), of the range of pesticide loads which may be expected in the area of interest. Simiarly, the "percent positive sites" indicate whether a particular pesticide is distributed over much of the area or has limited distribution. The NPMP information thus tends to be useful chiefly for estimating possible extremes in pesticide loads from large areas and is not applicable to unmonitored areas such as forestland.

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* HIF denotes Herbicide, Insecticide, and Fungicide.

It is imperative that the user of this function obtains up-to-date site or area-specific data on soil concentrations. Current NPMP data should be consulted, as should local sources of data, notably universities, state and local health departments, and environmental agencies.

5.2.2 Case 2: Water Insoluble Pesticides, Current Area-Specific Data Available

Case 2 covers the source with well-documented concentration data obtained by analysis of samples taken from the source, in combination with pesticide use data and knowledge of the persistence of the pesticide. If the source is sampled frequently at well-distributed sampling sites, other information may be unnecessary. If the sampling is less complete, information on application rates and persistency will help deduce concentrations. The basic loading function is the same as for Case 1, i.e., Eq. (5-1). The values used for C(HIF) are determined from different sources than the sources for Case 1. Guidelines for determining C(HIF) follows:

1. Document beginning of the season residual concentrations, if any, of pesticides of interest.

2. Obtain data on application rates and schedules. Estimate concentration in surface soils (3 to 5 cm (1 to 2 in.)) of applied pesticide, taking into account the fraction of the pesticide which reaches the soil surface, and the depth the pesticide is mixed into the soil.

3. Add values from Steps 1 and 2 to obtain an initial concentration.

4. From information on pesticide persistency, estimate fraction of pesticide which remains after appropriate intervals of time: days for short-lived pesticides; months for pesticides with growing season persistency; and years for long-lived pesticides.

5. If pesticide is applied more than once per season, repeat Steps 1, 2, 3, and 4 for each application and estimate concentration throughout growing season and up to the start of the next growing season.

6. Calculate sediment loads, $Y(S)_E$, from sources by procedures presented in Section 3.0.

Calculate annual average $Y(S)_E$ if pesticides are relatively persistent and a reasonable yearly average value can be deduced. Calculate Y(HIF) from Eq. (5-1):

$$Y(HIF)\ \text{average} = Y(S)_E\ \text{average} \cdot C(HIF)\ \text{average} \cdot 10^{-6}$$

Calculate $Y(S)_E$ by months if pesticide concentrations vary widely throughout the year. Calculate Y(HIF) annual average, 30-day maximum and 30-day minimum by calculating monthly loads.

$$Y(HIF)\ \text{monthly} = Y(S)_E\ \text{monthly} \cdot C(HIF) \cdot 10^{-6}$$

Sum for a year to obtain annual average. Select 30-day maximum and 30-day minimum from computed monthly loads.

5.2.3 Case 3: Water Soluble and Water Insoluble Pesticides, Stream to Source Approach

Water soluble pesticides are in part transported overland in surface runoff and absorbed on sediments; they are also susceptible to migration downward in the soil column, where they are not subject to overland transport mechanisms. For lack of a procedure for predicting the ultimate fate of the fraction which moves downward from the surface, it has been bypassed in loading function development. That fraction transported overland may be estimated if runoff is measured and analyzed for pesticides. Specifically, watershed hydrographs for storm events must be determined by measurement, or calculated from predictive models,[1-4] and concentrations of pesticides determined for water samples collected at various stages of the hydrograph(s).* The data so obtained convert to pesticide loads by multiplying increments of flow by the respective concentration values:

$$Y(HIF)\ \text{storm event} = \sum_i Q_i C_i \cdot a \qquad (5\text{-}2)$$

where Q_i = increment of flow

C_i = C(HIF) of the i^{th} increment of flow

$a = 10^{-6}$ if dimensions of Q and C are liters and ppm

$a = 62 \times 10^{-6}$ if dimensions of Q and C are feet^3 and ppm

Units of Y(HIF): kilograms (lb)

---

* Base flow (nonstorm event) stream data on flows and concentrations will not suffice. Many pesticides decompose in water and may become trapped in bottom sediments. Concentrations under base flow conditions do not accurately reflect storm event loads.

The storm event load can be distributed back to the land by several options; for example:

Uniformly over the watershed.
Nonuniformly to broad categories of sources, e.g., row crops.
Specifically to identified or suspect sources, in proportion to source size.

It will be necessary to sum storm events for the season, perhaps for the year, to obtain annual loads. The 30 day maximum loadings fall naturally out of cumulative storm event loads.

This procedure has several limitations and disadvantages. Extensive use will be costly, and limited use will not suffice to adequately describe large areas. An appropriate use is as follows: with selective runoff measurement and analysis it will be possible to develop the relatively modest inventory of data and experience needed to estimate pesticide loads for sensitive areas, e.g., an intensive agricultural area which depends heavily on herbicides and insecticides, and has a relatively stable and predictable pattern of use. Combination of accumulated information on pesticide use patterns with representative measured concentrations and loads of pesticides will more than adequately serve as a predictive "loading function." Since many of the persistent pesticides are being phased out, the peak loads which occur in storms which follow pesticide application are increasingly important. This basic approach will, if properly used, deal with this problem adequately.

5.3 GENERAL INFORMATION

5.3.1 Pesticide Solubility

The dividing line between solubility and insolubility is diffuse and is affected by factors such as the presence of other constituents in the solution phase, pH, soil acidity, and organic matter in soil. Solubility denotes, for purposes of the handbook, relatively little to moderate resistance to leaching, and insolubility denotes moderate to high resistance to leaching. Limited solubility data and indices of leachability are presented in Appendix G, Table G-2. A pesticide with a leaching index of one or two is treated as "insoluble." An index of three or four is treated as "soluble."

5.3.2 Pesticide Persistence

General information on persistence is presented in Appendix G. Particularly relevant to load calculation are the data which, though only semiquantitative, permit estimation of rates of disappearance in soils. Residues, concentrations and percent losses of selected pesticides are compiled from recent literature and presented in Table G-3.

5.4 LOAD CALCULATION: EXAMPLES

Case 1 Method

Conditions: Refer to Section 3.0, entitled "Sediment Loading Function."

Dieldrin
Continuous corn
$A = 73$ ha
$Y(S)_E$ (30-day maximum) = 117 kg/ha/day
$Y(S)_E$ (annual average) = 36 kg/ha/day
$C(I)$ range, 0.01 to 0.58 ppm from Appendix F, Table F-3

Probable minimum load, annual average
$Y(I) = 36 \cdot 0.01 \cdot 73 \times 10^{-6} = 26 \times 10^{-6}$ kg/day

Probable maximum load, annual average
$Y(I) = 36 \cdot 0.58 \cdot 73 \times 10^{-6} = 1{,}524 \times 10^{-6}$ kg/day

Case 2 Method

Conditions: Refer to above example.

2,4-D
Application rate: 5 kg/ha
Application date: 15 June
Persistence: 4 weeks (Appendix G)
Residue zero at season start
$Y(S)_E$ = 117 kg/ha/day, for 1-month period, 15 June to 15 July

Calculations

Initial concentration in erodible soil layer (5 cm), about 5 ppm
Average concentration, estimated from persistence information equals 2 to 3 ppm for 15 June to 15 July period
$Y(H) = 117 \times 2.5 \times 73 \times 10^{-6} = 0.0214$ kg/day
$Y(H)$ (30-day maximum) = 0.0214 kg/day

5.5 LIMITATIONS IN USE

As stated earlier, pesticide behavior in the environment is both complex and variable, and the accuracy of estimation reflects these complexities.

The National Pesticide Monitoring Program, which serves as the basis for Case I, contains data which generally indicate levels of pesticides in soils throughout the country, and the frequency at which pesticides are observed is an indication of the intensity of the use pattern. The data and the Case I method should, however, be used only to derive an estimate of loads over very large areas, and the results should be presented with two qualifications: (a) that peak loads for nonpersistent pesticides are apt to be overlooked by the method; and (b) that pesticides which leach readily into the soil (and thus may contaminate subsurface waters) will not be accounted for. Examination of the range of values reported in the NPMP system reveals the fact that loads calculated from that data base may differ substantially from actual loads, especially if one wishes to apply calculated loads to a specific small area.

The Case II method depends upon area-specific and pesticide-specific data, and thus will calculate loads considerably closer to actual values than Case I. Since the data requirement is fairly extensive, its use is probably restricted to a small region--several counties perhaps--in which pesticide use is uniform and other parameters are also relatively uniform. The Case II method will, with care in use, be somewhat sensitive to peak loads, i.e., when it rains soon after pesticide application.

The Case III method can be accurate with care in use. As indicated in Section 5.2, the approach is probably best used to develop data and experience at local or regional levels, so that pesticide loads can be estimated with confidence from a base of accumulated local experience.

Estimates of accuracy expected for Cases I through III are presented in Table 5-1.

Table 5-1. ESTIMATES OF ACCURACY FOR PESTICIDES

	Annual average (g/ha/year)		Storm event (g/ha/day)	
	Estimated	Probable range	Estimated	Probable range
Case 1 method	1-10	0.001-100		
(insoluble pesticide)			Not applicable	
Case 2 method	1	0.01-10	1	0.1-10
(insoluble pesticide)	20	5-50	20	5-50
Case 3 method	1	0.1-5	1	0.1-5
(soluble and insoluble pesticides)	20	10-50	20	10-50

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SECTION 6.0

SALINITY IN IRRIGATION RETURN FLOW

6.1 INTRODUCTION

The accurate prediction of salinity emissions in irrigation return flows requires detailed knowledge of the particular system being studied. Practice has shown that salinity in irrigation return flows varies widely in differing regions of the country because of the specific natures of the soils, underlying geological formations, regional topography, and irrigation practices. As a result, a simple "loading function" applicable to all irrigation cases has no validity under present state of the art. A discussion of the data needs for irrigation return flow salinity models pointing out this fact has been prepared by the Environmental Protection Agency.1/

For purposes of making assessments of salinity from irrigation return flow, three optional methods are suggested in this section. The user is cautioned, however, that the methods are not universally applicable and hence may yield estimates that are not accurate. The most accurate prediction method remains long-term monitoring of the particular irrigation area to quantify actual salinity outputs in irrigation return flow.

The three procedures presented here for estimating salinity in irrigation return flow are:

Option I - Source to Stream Approach: The first option involves the estimation of irrigation water percolating into groundwater, which finds its way into surface waters by subsurface return mechanisms. This approach is valid for only a few areas of the country when valid relationships between applied water and return flows exist. Furthermore, this option should not be used in cases of spray irrigation where evaporative losses associated with the applied water are significant. This option is most valid in those cases where the total dissolved solids in groundwater contributing to return flow are very high (ca. 10 times) compared to total dissolved solids concentrations in applied water.

Option II - Stream to Source Approach: The second option involves a back-estimation procedure for salinity discharges in irrigation return flow. Salinity measurements taken at sampling points above and below irrigated areas will establish the amount of salt discharged in the area drained by the stream between the two points. This salt load, however, includes that discharged from background, salt springs, and point sources, as well as that discharged from irrigation return flow. This method requires a good definition of salinity sources other than irrigation return flow, particularly that of background. This method is the one which has been most widely used by others, especially where the total salinity loads are measured at the discharge points of drainage basins.

Option III - Loading Values for Salinity in Irrigation Return Flow: A third method for estimating salinity loads in irrigation return flows is the use of loading values established for given areas through reduction of stream monitoring data. A list of such loading values for areas in the Colorado River basin are presented. These values are applicable only to the particular region and should not be used except where indicated.

6.2 OPTION I: SOURCE TO STREAM APPROACH

6.2.1 Load Estimation Equation and Information Needs

An equation to estimate salinity in irrigation return flow has been formulated based upon data reported by Skogerboe et al.[2] The equation is:

$$Y(TDS)_{IRF} = a \cdot A \cdot C(TDS)_{GW} \cdot [IRR + Pr - CU] \qquad (6\text{-}1)$$

where $Y(TDS)_{IRF}$ = salinity load in irrigation return flow, kg/day (lb/day)

A = area under irrigation, ha (acre)

IRR = volume of water added to crop root zone annually for irrigation, cm (in.)

Pr = annual precipitation, cm (in.)

CU = annual consumptive use of water in growing crops, cm (in.)

$C(TDS)_{GW}$ = average concentration of total dissolved solids in groundwater contributing to subsurface return, ppm

a = conversion factor to obtain proper units of load. If Y is in kg/day, $a = 2.7 \times 10^{-4}$; if Y is in lb/day, $a = 6.2 \times 10^{-4}$

The volume of water applied to the crop root zone, IRR , can be determined by subtracting the volume of tailwater from the total water delivered to the irrigation site. The best information would be available from local irrigation districts.

Annual precipitation, Pr , is available from local weather data. Average annual precipitation can be used for purposes of estimating gross salinity loads.

The CU factor, consumptive use, can be estimated by standard formulae such as Jensen-Haise Method or the Blaney-Criddle Method. The Jensen-Haise Method for estimating consumptive use is described in detail in the Skogerboe et al. report on irrigation scheduling.2/ Information needed for the Blaney-Criddle consumptive use formula can be found in Todd's Water Encyclopedia,3/ for the West.

The key data needed in the irrigation return flow loading function are the groundwater total dissolved solids concentrations, $C(TDS)_{GW}$. These values represent that groundwater which contributes to perennial streamflow. The best data would be that obtained from observation wells in the irrigation plot, information which is not always available. For large irrigation areas, one should use an average groundwater TDS value obtained from several observation wells.

The user is cautioned to avoid using the Option I method for cases involving sprinkler irrigation methods. This method does not account for evaporation losses during application. If valid information is available concerning evaporation losses, it should be incorporated into the estimation procedure. Evaporation basically will cause an increase in the TDS of applied water which will show up as increased TDS in the groundwater contributing to return flow.

6.2.2 Load Calculation - Irrigation Return Flow

Load calculation involves three basic steps:

1. Obtain necessary information for Eq. (6-1) from sources identified above.

2. Substitute values into Eq. (6-1).

3. Compute loads.

The Option I loading value equation (Eq. (6-1)) has been used to estimate loads which can be compared directly to those reported by Skogerboe et al.[2/] Data used as inputs to the equation were those measured by Skogerboe. Data inputs for Eq. (6-1) are tabulated in Table 6-1, together with calculated loads. These are compared with reported loads.

Table 6-1. COMPARISON OF SALINITY LOADS OBTAINED WITH OPTION I LOAD ESTIMATION EQUATION WITH REPORTED SALINITY LOADS[2/] IN THE GRAND VALLEY, COLORADO

(Essential information: $a = 6.2 \times 10^{-4}$; $C(TDS)_{GW} = 6{,}700$ ppm)

Equation factors	Plot No. 1	Plot No. 2	Plot No. 3	Plot No. 4	Plot No. 5
A (acre)	8.5	8.5	25.7	15.0	10.7
IRR (in.)	31.4	23.3	42.1	29.1	24.7
P_r (in.)	1.0	4.1	1.2	2.7	3.3
CU (in.)	26.9	19.1	33.5	20.7	17.1
Calculated load (lb/day)	194	293	1,046	692	484
Reported load (lb/day)	379	344	1,291	521	545

As can be seen from the comparison, the calculated loads compare reasonably with reported loads in four out of the five cases. One reason for discrepancies between the calculated and reported values may be that the equation disregards changes in soil moisture storage during the year. In general, the changes in soil moisture storage which occur during and between irrigation events should add to zero over an annual period, and hence would have little effect on annual irrigation return flow volume. Some irrigation water applied to the crop root zone is retained as soil moisture, and hence does not show up as either consumptive use or irrigation return flow. Soil moisture storage is an information input which is not readily accessible.

The Option I loading value equation should be considered only as a first approximation method for estimating salinity in irrigation return flow. Its usefulness will depend primarily upon three factors: (1) the concentration of total dissolved solids in shallow groundwater which is transmitted to surface waters as subsurface return; (2) reliable estimates of the volume of applied water, tailwater, and return flows; and (3) good information pertaining to consumptive losses in the complete irrigation system. If these data are deemed insufficient, one should estimate salinity in irrigation return by other procedures.

6.3 OPTION II: STREAM TO SOURCE APPROACH

6.3.1 Loading Equation and Information Needs

A second method for estimating salinity loads from irrigation return flow involves the stream to source approach. In this option, salinity loads in streams are determined above and below areas of irrigation. Differences in salinity loads represent total salt being discharged by the area by background and point sources, as well as irrigation return flow. Therefore, salt loadings from irrigation return flow are determined by subtracting out contributions from background and from point sources.

The Option II loading value equation is:

$$Y(TDS)_{IRF} = a \cdot \left[Q(str)_B \cdot C(TDS)_B - Q(str)_A \cdot C(TDS)_A\right] - Y(TDS)_{BG} - Y(TDS)_{PT} \quad (6\text{-}2)$$

where $Y(TDS)_{IRF}$ = yield of salinity in irrigation return flow, kg/day (lb/day)

$Y(TDS)_{BG}$ = salinity load contribution of background, kg/day (lb/day)

$Y(TDS)_{PT}$ = salinity load contribution of point sources, kg/day (lb/day)

$Q(str)_B$ = streamflow of surface water below irrigated areas, liters/sec (cfs)

$Q(str)_A$ = streamflow of surface waters above irrigated areas, liters/sec (cfs)

$C(TDS)_B$ = concentration of total dissolved solids in stream below irrigated area, ppm

$C(TDS)_A$ = concentration of total dissolved solids in stream above irrigated areas, ppm

a = conversion constant needed to obtain proper units of load. If flow units are liters/sec, a = 0.0864 (metric system, kg/day). If flow units are cfs, a = 5.39 (English system, lb/day).

Flow and concentration data obtained above and below irrigated areas can be obtained from U.S. Geological Survey records of the region, or in some cases from local water quality monitoring data. The use of these data in the loading value equation will indicate total salt added to surface waters between two points.

The salt load from point sources in the area under consideration can be determined using information supplied by persons responsible for the point sources. Point source contributions may be estimated from data contained in discharge permit applications available from state and local pollution control agencies, and from regional Environmental Protection Agency offices. The total dissolved solids from the individual point sources in the area are summed to yield total point source contributions.

The most difficult piece of information to be obtained is quantities of salt discharged from background. In many cases, particularly in the arid and semiarid regions where irrigation is intensive, this estimation can only be accomplished by knowledge of the characteristics of the particular area.

This estimation relies upon the judicious use of information concerning background in a particular region. The use of broad general definitions of background such as those presented in Section 12.0 of this handbook is not recommended for the Option II method for salinity in irrigation return flow. An estimation of background TDS levels may be made using the U.S. Geological Survey's Hydrologic Investigations Atlas, HA-61, Plate 1.[4/] This plate contains information concerning dissolved solids concentration for surface waters throughout the conterminous United States. It does not differentiate between point and nonpoint contributions to salinity, nor does it account for cumulative effects of runoff from a wide variety of sources into stream water. The use of this map is recommended as a first approximation of background.

The equation needed to define background total dissolved solids load can be formulated in two ways, depending upon the units of flow. If flow is measured as annual average runoff, the equation is:

$$Y(TDS)_{BG} = a \cdot A \cdot Q(R) \cdot C(TDS)_{BG} \qquad (6\text{-}3)$$

where $Y(TDS)_{BG}$ = salinity load from background, kg/day (lb/day)

A = area under consideration, ha (acre)

$Q(R)$ = flow, as annual average runoff, cm (in.)

$C(TDS)_{BG}$ = concentration of background total dissolved solids as determined by local information, ppm

a = conversion constant to obtain proper units of load. If load is kg/day, $a = 2.7 \times 10^{-4}$; if load is lb/day, $a = 6.2 \times 10^{-4}$.

If flow is measured as actual flow in liters per sec (cfs), the equation for estimating salinity loads in background becomes:

$$Y(TDS)_{BG} = a \cdot C(TDS)_{BG} \cdot [Q(str)_B - Q(str)_A] \qquad (6\text{-}4)$$

where $Q(str)_B$ and $Q(str)_A$ are the flows below and above the irrigated areas, respectively. If the load is kg/day, $a = 0.0864$; if the load is lb/day, $a = 5.39$. The concentration of total dissolved solids in background, $C(TDS)_{BG}$, is the same as defined previously.

After proper information has been obtained, it is substituted into the correct background total dissolved solids equation (Eqs. (6-3) or (6-4)), and background total dissolved solids load computed.

6.3.2 Option II Load Calculation

The step-by-step procedure presented below is used for Option II stream to source load calculations.

1. Obtain needed flow and concentration information for points above and below irrigated areas. In many cases, information obtained at the mouth of a drainage basin containing irrigated agriculture is sufficient, thus obviating the need for above stream data.

2. Estimate total salinity loads above and below irrigated areas using proper flow and concentration data. The total salinity load from irrigated areas, including its nonirrigated land uses, is determined by subtracting upstream load from downstream load, via Eq. (6-2).

3. Obtain data pertaining to point source contribution and sum individual point sources to obtain total point load.

4. Determine background total dissolved solids load using Eqs. (6-3) or (6-4) and procedures outlined previously in this section.

5. Estimate salinity load from irrigation return flow by subtracting values obtained in Steps 3 and 4 from the value obtained in Step 2.

$$Y(TDS)_{IRF} = \text{Step 2} - \text{Step 3} - \text{Step 4}$$

$$= Y(\text{total}) - Y(\text{background}) - Y(\text{point})$$

The Option II stream to source approach for estimating salinity loads in irrigation return flow has been applied to several subbasins of the Colorado River. Values generated by the Option II load estimation equation have been compared with values reported by the Environmental Protection Agency in Appendix A to their report concerning the "Mineral Quality Problem in the Colorado River Basin." Results of the comparison are presented in Table 6-2.

Table 6-2. COMPARISON OF SALINITY LOADS ESTIMATED BY OPTION II METHODS WITH THOSE REPORTED BY EPA[a]

Basin	Flow at basin mouth (cfs)	C(TDS) at basin mouth (ppm)	$C(TDS)_{BG}$ estimate (ppm)	Calculated load using Option II (tons/day)	Reported load (tons/day)
Black Fork[b]	663	495	200	527	481
Gunnison[c]	3,100	558	200	2,990	3,100
Big Sandy Creek[d]	140	2,190	1,300	336	200
White[e]	901	472	300	217	20

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[a] U.S. Environmental Protection Agency, Regions VIII and IX, "Natural and Man-Made Conditions Affecting Mineral Quality," Appendix A of EPA Report, The Mineral Quality Problem in the Colorado River Basin (1971).

[b] Reference a, Figure 20.

[c] Reference a, Figure 34.

[d] Reference a, Figure 18.

[e] Reference a, Figure 25.

From the data in Table 6-2, it is seen that Option II tends to overpredict salinity in irrigation return flow. The overprediction may be due to conservative estimates of background contributions, or to emissions from unknown natural point sources such as salt springs. The data in Table 6-2 clearly point out the fact that background, particularly that in arid or semiarid areas, needs to be carefully considered. For example, the high background level in the Big Sandy Creek area is due to water seepage from saline lake beds in the area. Such characteristics must be known if the Option II approach is to yield valid results.

6.4 OPTION III: LOADING VALUES FOR SALINITY LOADS IN IRRIGATION RETURN FLOW

Perhaps the most useful method of estimating salinity loads is through loading values determined for particular regions. Lists of such values are presented in Tables 6-3 through 6-7 for subbasins in the Colorado River basin, and for irrigated regions in California.

Studies in the Twin Falls area and the Colorado River basin indicate that the range of values for salt pickup from irrigated lands is roughly 1.3 to 22 MT/ha/year (0.5 to 8 tons/acre/year).[5/] An average salt pickup rate might be 5 MT/ha/year (2 tons/acre/year). On a per day basis, the range becomes 3 to 50 kg/ha/day (3 to 44 lb/acre/day), and the average becomes 12 kg/ha/day (11 lb/acre/day).

6.5 ESTIMATED RANGE OF ACCURACY

The accuracy of the three optional procedures for estimating salinity loads from irrigation return flow will be no better than the accuracy of the input data. For this particular system, the quality of the input data is likely to be quite variable. More often than not, the quality of input data will be less than that desired by the user. In addition, the estimation procedure mechanisms tend to compound errors inherent in the input data.

With these factors taken into account, ranges of error for Options I and II have been estimated. The Option III method--loading values--is the most accurate method if proper input data are available. However, its use requires loading values generated from on-site data, and such data are most often not available.

Table 6-8 presents the estimated range of error for the Option I (Source to Stream) procedure. The error is estimated for several ranges of areas which emit an average annual load of either 1 or 10 MT/year.

Table 6-3. SALT YIELDS FROM IRRIGATION IN GREEN RIVER SUBBASIN[a]

Area	Average salt yield (tons/acre/yr)	Average salt yield (kg/ha/day)	Average salt yield (lb/acre/day)
Green River above New Fork River	0.1	0.6	0.5
Big Sandy Creek	5.6	34.3	30.7
Blacks Fork in Lyman area	2.4	14.7	13.2
Hams Fork	0.3	1.8	1.6
Henry's Fork	4.9	30.1	26.9
Yampa River above Steamboat Springs	0.2	1.2	1.1
Yampa River, Steamboat Springs to Craig	0.4	2.5	2.2
Milk Creek	1.0	6.1	5.4
Williams Fork River	0.3	1.8	1.6
Little Sanke above Dixon	0.3	1.8	1.6
Little Sanke, Dixon to Baggs	0.5	3.1	2.7
Ashley Creek	4.2	25.8	23.0
Duchesne River	3.0	18.4	16.4
White River below Meeker	2.0	12.3	11.0
Price River	8.5	52.2	46.6
San Rafael River	2.9	17.8	15.9

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a/ U.S. Environmental Protection Agency, Regions VIII and IX, "Natural and Man-Made Conditions Affecting Mineral Quality," Appendix A of EPA Report, The Mineral Quality Problem in the Colorado River Basin (1971).

Table 6-4. SALT YIELDS FROM IRRIGATION IN UPPER COLORADO MAIN STEM SUBBASIN[a]

Area	Average salt yield (tons/acre/yr)	Average salt yield (kg/ha/day)	Average salt yield (lb/acre/day)
Main stem above Hot Sulphur Springs	0.3	1.8	1.6
Main stem, Hot Sulphur Springs to Kremmling	0.9	5.5	4.9
Muddy Creek Drainage Area	2.4	14.7	13.2
Brush Creek	0.7	4.3	3.8
Roaring Fork River	3.5	21.5	19.2
Colorado River Valley, Glenwood Springs to Silt	2.3	14.1	12.6
Colorado River, Silt to Cameo	3.5	21.5	19.2
Grand Valley	8.0	49.1	43.8
Plateau Creek	0.9	5.5	4.9
Gunnison River above Gunnison	0.3	1.8	1.6
Tomichi Creek above Parlin	0.3	1.8	1.6
Tomichi Creek, Parlin to mouth	0.3	1.8	1.6
Uncompahgre above Dallas Creek	4.5	27.6	24.7
Lower Gunnison	6.7	41.1	36.7
Naturita Creek near Norwood	2.8	17.2	15.3

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a/ U.S. Environmental Protection Agency, Regions VIII and IX, "Natural and Man-Made Conditions Affecting Mineral Quality," Appendix A of EPA Report, The Mineral Quality Problem in the Colorado River Basin (1971).

Table 6-5. SALT YIELDS FROM IRRIGATION IN SAN JUAN RIVER SUBBASIN[a]

Area	Average salt yield (tons/acre/yr)	(kg/ha/day)	(lb/acre/day)
Fremont River above Torrey, Utah	0.4	2.5	2.2
Fremont River, Torrey to Hanksville, Utah	5.8	35.6	31.8
Muddy Creek above Hanksville, Utah	3.1	19.0	17.0
San Juan above Carracas	2.7	16.6	14.8
Florida, Los Pinos, Animas drainage	0.2	1.2	1.1
Lower Animas Basin	3.5	21.5	19.2
LaPlata River in Colorado	1.4	8.6	7.7
LaPlate River in New Mexico	0.3	1.8	1.6

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[a] U.S. Environmental Protection Agency, Regions VIII and IX, "Natural and Man-Made Conditions Affecting Mineral Quality," Appendix A of EPA Report, The Mineral Quality Problem in the Colorado River Basin (1971).

Table 6-6. SALT YIELDS FROM IRRIGATION IN LOWER COLORADO RIVER BASIN[a]

Area	Average salt yield (tons/acre/yr)	(kg/ha/day)	(lb/acre/day)
Virgin River	2.3	14.1	12.6
Colorado River Indian Reservation	0.5	3.1	2.7
Palo Verde Irrigation District	2.1	12.9	11.5
Below Imperial Dam (Gila and Yuma projects)	variable	-	-

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[a] U.S. Environmental Protection Agency, Regions VIII and IX, "Natural and Man-Made Conditions Affecting Mineral Quality," Appendix A of EPA Report, The Mineral Quality Problem in the Colorado River Basin (1971).

Table 6-7. SALT YIELDS FROM IRRIGATION FOR SELECTED AREAS IN CALIFORNIA[a/]

Area	Average salt yield (tons/acre/year)	(kg/ha/day)	(lb/acre/day)
North coastal	0.353	2.2	1.9
Central coastal	0.808	5.0	4.4
Sacramento	0.707	4.3	3.9
Delta-Central Sierra	0.974	6.0	5.3
San Joaquin	0.827	5.1	4.5
Tulare	0.768	4.7	4.2
Colorado Desert	10.9	67	60

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a/ California Regional Framework Study Committee for Pacific Southwest Inter-Agency Committee, Water Resources Council, "Comprehensive Framework Study, California Region, Appendix XV, Water Quality, Pollution, and Health Factors," June 1971.

Table 6-8. ESTIMATED RANGE OF ACCURACY FOR OPTION I (SOURCE TO STREAM) PROCEDURE FOR ESTIMATING SALINITY FROM IRRIGATION RETURN FLOW

Area considered (ha)	Calculated load (MT/ha/year)	Probable range of loads (MT/ha/year)
< 100	1	0.7 - 1.5
	10	8 - 13
100 - 1,000	1	0.5 - 3
	10	6 - 15
1,000 - 10,000	1	0.3 - 5
	10	4 - 20
> 100,000	1	0.1 - 10
	10	2 - 25

As can be seen from the table, the Option I procedure is deemed most accurate when used for small areas, and when larger loads are calculated. This aspect of accuracy arises because the Option I function is totally dependent upon local conditions such as total dissolved solids in groundwater, water consumptive use variations from crop to crop, irrigation water supplied to specific fields, and variation of deep percolation losses. If any of these data are extrapolated to larger areas, the variations in input data become wider, and hence the procedure becomes less accurate for large areas.

In principle, error in the Option I method can be minimized for large areas by summing up the values obtained for small areas. However, it is questionable whether such a summation would yield calculated values with any higher accuracy than those obtained using the Option II method.

Estimated ranges of error for the Option II (Stream to Source) procedure are given in Table 6-9. When Option II is used, the most accurate loads will be calculated when large areas are considered. The ranges shown in Table 6-9 assume that background salinity loads have been carefully considered. Since these background loads are the most uncertain component of the procedure, the breadth of the error range is determined by this uncertainty.

Table 6-9. ESTIMATED RANGE OF ACCURACY FOR OPTION II (STREAM TO SOURCE) PROCEDURE FOR ESTIMATING SALINITY FROM IRRIGATION RETURN FLOW

Area considered (ha)	Calculated load (kg/ha/day)	Probable range of loads (kg/ha/day)
< 1,000	1	0.2 - 5
	10	4 - 30
1,000 - 10,000	1	0.5 - 3
	10	6 - 20
> 100,000	1	0.8 - 1.5
	10	8 - 13

The Option II method is deemed to be less accurate when small areas are considered. The decrease in accuracy for small areas is inherent due to uncertainty in flow measurements as well as uncertainty in background. In general, small areas are associated with small streams draining the area. The amount of variation for small streams is usually quite high (and more unpredictable) than that of large streams.

No estimate of error has been given for the Option III procedure for estimating salinity loads from irrigation return flow. The accuracy of this option--use of salinity loading values--depends chiefly on the trouble taken by the user to characterize his region and develop site-specific information on his loadings. This option can be the most accurate of the three discussed, provided that the values used are accurate.

The availability of accurate loading values for the Option III approach is quite limited. Accurate values can be obtained through long term monitoring and analysis of irrigated areas, an expensive and time consuming operation. However, various mathematical methods for predicting salinity in irrigation return flow are being developed. These models will tend to describe the complicated relationships between the water used for irrigation and the land being irrigated which result in salinity emissions. It may be that at some future time, these models will be sufficiently validated so that their outputs can produce loading values for use in the Option III procedure. The user of this handbook is encouraged to keep abreast of these modeling projects so that their output can be used to obtain accurate estimates of salinity from irrigation return flow.

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SECTION 7.0

ACID MINE DRAINAGE

7.1 INTRODUCTION

The emission of acid mine drainage arises from land disturbances created by coal and metals mining activities. The mine drainage arises because of atmospheric and hydrologic actions on pyritic materials associated with the mined materials. The pyritic materials may be in residues left behind at the mined-out site, or in residues produced by coal processing or mineral beneficiation. If pyrites (or other sulfurous materials) are not associated with a particular mined product, e.g., quarrying, sand and gravel operations, etc., then acid mine drainage will not occur. Thus, the presence or absence of pyritic materials is the determining factor for nonpoint emissions of mine drainage.

Mine drainage can arise from active and inactive mines and from underground and surface activities. In addition, mine drainage can arise from processing wastes, e.g., tailings piles and gob piles. In considering nonpoint emissions from these latter sources, processing wastes disposed of on the land surface are considered as surface mines.

Basically, regional mine drainage problems arise because of an assemblage of individual sources in an area. A procedure for estimating mine drainage loads based upon the statistical distribution of individual sources is presented here as Option I. The procedure was developed using data gathered by Environmental Quality Systems, Inc., in a study dealing with estimation of mine drainage emissions in the Monongahela River Basin,[1/] and from data obtained for the Appalachian Regional Commission[2/] for their report concerning mine drainage in Appalachia.[2] This procedure is fundamentally a source to stream loading function. On the other hand, sulfate analysis of surface waters are key indicators of nonpoint emissions of mine drainage, since sulfate is the end product of atmospheric/hydrologic reactions with pyrite. Thus, an Option II estimation procedure is presented which uses the stream to source approach and is based on sulfate concentrations in surface waters. A brief description of these two options follow.

Option I - Source to Stream Approach: A loading estimation procedure is presented which relates the number of total sources in an area, the distribution of these sources among four categories (active underground, active surface, inactive underground, and inactive surface), and neutralization of acidic products of pyrite weathering with background alkalinity. This approach is particularly useful for heavily mined areas of the country, such as the coal mining regions of Appalachia. In other areas where mining is less concentrated, this statistical approach may not be adequate.

Option II - Stream to Source Approach: The second option involves comparing sulfate loadings found in surface waters with sulfate loadings expected from natural background. Increases in sulfate loading as surface waters move through an area over the background contribution can be attributed to nonpoint emissions of mine drainage in the area. This second approach should be considered when detailed information about the number of sources is unknown, where mining density is low, or when streamflow data are deemed more appropriate to use.

7.2 OPTION I: SOURCE TO STREAM APPROACH

7.2.1 Loading Function and Information Needs

The loading function for the Option I approach contains three fundamental elements: the number of potential sources of mine drainage; the amount of raw acidity formed from the sources; and the neutralization capacity of the background. The second element--amount of raw drainage formed--involves the statistical distribution term to account for the widely variable source-to-source loads arising from the individual sources. The loading function is:

$$Y(AMD) = N[K_a \cdot (I_{AU} + I_{AS} + I_{IU} + I_{IS}) - K_b \cdot Q(R) \cdot C(Alk)_{BG}] \qquad (7\text{-}1)$$

where N = total number of sources which are potential emitters of acid mine drainage

Statistical Distribution Term

K_a = constant representing the raw acid load generated by the "typical" site. A range of values for K_a is presented in Table 7-1, and discussed in Section 7.2.2.

I_{AU}, I_{AS}, I_{IU}, I_{IS} = load index values for the number of Active Underground sources, Active Surface sources, Inactive Underground sources, and Inactive Surface sources. The load index values are presented in Table 7-2, and discussed in Section 7.2.3.

Background Neutralization Term

K_b = constant representing the neutralization capacity of background alkalinity for raw acid produced at the "typical" site. A range of values for K_b is presented in Table 7-1, and discussed in Section 7.2.2.

$Q(R)$ = flow as annual average runoff in the area, cm/year (in/year)

$C(Alk)_{BG}$ = concentration of background alkalinity in the area, ppm as $CaCO_3$. $C(Alk)_{BG}$ can be determined through use of an isoalkalinity map (see Figure 7-1, Section 7.2.4).

7.2.2 Constants K_a and K_b in Option I Loading Function

Description of the acid mine drainage discharge from the "typical" source was determined by subjecting a number of mine drainage data obtained in the Monongahela River Basin[1/] to regression analysis. These data represented the acid load discharged at specific sites from about 7,000 potential sites. The regression analysis indicated that the distribution of mine drainage quantities from the 7,000 sources could be well fit (index of determination = 0.998) to a hyperbolic function dependent upon (a) the number of sources, (b) the quantity of mine drainage from the largest source, and (c) the cumulative amount of mine drainage emitted from all sources. The regression equation has the form:

$$\lim_{N \to \infty} \frac{A \cdot N}{\sum_{i=1}^{N} B_i + A \cdot N} = 1 \qquad (7\text{-}2)$$

Table 7-1. VALUES OF K_a AND K_b FOR ACID MINE DRAINAGE OPTION I LOADING FUNCTION

	Units of load	K_a		K_b	
		Value of K_a	Range of K_a	Value of K_b	Range of K_b
Metric	kg/day	130	110-150	0.15	0.10-0.20
English	lb/day	280	250-320	0.62	0.35-0.75

Table 7-2. LOAD INDEX VALUES FOR ACTIVE AND INACTIVE SURFACE AND UNDERGROUND MINES

Fraction of mines in category	Load index			
	Active underground	Active surface	Inactive underground	Inactive surface
0.00	0.00	0.00	0.00	0.00
0.05	0.33	0.08	0.13	0.03
0.10	0.50	0.16	0.23	0.06
0.15	0.60	0.22	0.31	0.08
0.20	0.67	0.27	0.37	0.11
0.25	0.71	0.32	0.42	0.13
0.30	0.75	0.36	0.47	0.15
0.35	0.78	0.39	0.51	0.17
0.40	0.80	0.43	0.54	0.19
0.45	0.82	0.45	0.57	0.21
0.50	0.83	0.48	0.60	0.23
0.55	0.85	0.50	0.62	0.24
0.60	0.86	0.53	0.64	0.26
0.65	0.87	0.55	0.66	0.28
0.70	0.88	0.56	0.67	0.29
0.75	0.88	0.58	0.69	0.31
0.80	0.89	0.60	0.70	0.32
0.85	0.89	0.61	0.71	0.33
0.90	0.90	0.63	0.72	0.35
0.95	0.90	0.64	0.74	0.36
1.00	0.91	0.65	0.75	0.37

where A = the quantity of mine drainage from the largest source

$\sum_{i=1}^{N} B_i$ = the cumulative amount of mine drainage from all sources

N = the number of potential mine drainage sources in the area

The ratio of $\sum_{i=1}^{N} B_i$ to N thus determines the acid load from the "typical" site. Furthermore, the equation implies that the load will be more accurate when the number of sources considered becomes very large.

A part of the raw mine drainage generated within the mining area will have been neutralized by background alkalinity before it is discharged to surface waters. From the consideration of the background neutralizing capacity in the Monongahela River basin, it has been possible to establish values of K_a and K_b for the loading function (7-1) based upon the regression analysis represented by Eq. (7-2). These values are presented in Table 7-1.

The value K_a represents the raw acid generated at the "typical" mine site as determined by Eq. (7-2). The value K_b represents the neutralization of part of the raw acid by background alkalinity in the area directly affected by the "typical" site.

7.2.3 Load Index Factors for Option I Loading Function

The K_a values presented in Table 7-1 have been established based on data pertaining to the Monongahela River basin. In order to use them in other regions of the country, the K_a term must be corrected to reflect the distribution of potential mine drainage sources. This correction is accomplished through the use of "load index factor" determined in the following manner:

The total number of sources are separated into four components: number of active underground (AU), active surface (AS), inactive underground (IU) and inactive surface (IS). The fraction of each source is determined for each category by dividing the number of sources in a certain category by the total number of sources.

After the category fractions have been determined, a load index value is found in Table 7-2 for each category. The first column of Table 7-1 indicates the fraction of mine in each category; subsequent columns contain the load index value for each category. This procedure is exemplified in Table 7-3, using a hypothetical situation involving 1,800 mines.

Table 7-3. EXAMPLE OF DETERMINATION OF LOAD INDEX VALUES

	Number of sources	Fraction of sources	Load index
Active underground	180	0.10	0.50
Active surface	450	0.25	0.32
Inactive underground	630	0.35	0.51
Inactive surface	540	0.30	0.15
Total	1,800	1.00	1.48

After fractions of mines have been determined in each category, the appropriate load index value is established for each category by referring to the appropriate column in Table 7-2. After the individual load index values have been determined, they are added together to yield a total load index value required for the loading function. The total is the factor $(I_{AU} + I_{AS} + I_{IU} + I_{IS})$ in the loading function.

The load index values have been established by proportionating the total load and total number of sources (as determined by the regression analysis results of Eq. (7-2)) into contributions from active underground, active surface, inactive underground, and inactive surface sources in the Monongahela River basin. The bases for the proportionment were obtained from data in the 1969 Appalachian Regional Commission report concerning mine drainage.[2] This exercise yielded a series of four equations defining load index values for each of the four types of mine drainage sources. The equations from which the load index values in Table 7-2 were derived are:

$$I_{AU} = \frac{n_{AU}}{0.10 + n_{AU}} \quad (7\text{-}3)$$

$$I_{AS} = \frac{n_{AS}}{0.54 + n_{AS}} \quad (7\text{-}4)$$

$$I_{IU} = \frac{n_{IU}}{0.34 + n_{IU}} \quad (7\text{-}5)$$

$$I_{IS} = \frac{n_{IS}}{1.70 + n_{IS}} \quad (7\text{-}6)$$

where n_{AU} , n_{AS} , n_{IU} , and n_{IS} are the fractions of mines in each of the four categories.

$$n_{AU} + n_{AS} + n_{IU} + n_{IS} = 1.0 \qquad (7\text{-}7)$$

The total number of sources in an area is determined by study of state and local historical records. Basically, what is needed is the number of active and inactive underground and surface sources. The total number of sources need not be an exact count; a reliable estimate is quite satisfactory for use in the loading function.

Information concerning active sources can be found in the annual Minerals Yearbook, published by the U.S. Bureau of Mines. An alternate source of information about active sources will be state and local permit programs. Uncontrolled waste piles associated with active mines should be counted as active surface mines.

Information about inactive mines may be more difficult to obtain. Probably the best source of information on inactive mines will come through analysis of historical records of the area. These records should be available in state archives.

7.2.4 Background Alkalinity Term for Option I Loading Function

The K_b values presented in Table 7-1 have also been established from Monongahela River basin data. These too must be corrected in order to reflect changes in the neutralizing capacity of background. The correction factors involve alkalinity concentrations in background and average annual runoff.

Background alkalinity concentrations are determined by locating mining areas on the iso-alkalinity map (Figure 7-1), estimating concentration, and using this value in the alkalinity term. If other values of background alkalinity concentrations are deemed more appropriate than those shown on the map, then they should be used instead. In areas afflicted with acid mine drainage emissions, one should be cautious about using "unaffected" stream values of alkalinity. Although data may have been generated in areas unaffected by mining activity, unknown sources of mine drainage may be present which would lower background alkalinity estimates.

Average annual runoff can be estimated from standard runoff maps such as that in the U.S. Geological Survey's National Atlas, Plates 118 and 119.

7.2.5 Procedure for Using Option I Loading Function

The procedure for putting together components of the source to stream loading function to estimate levels is outlined below.

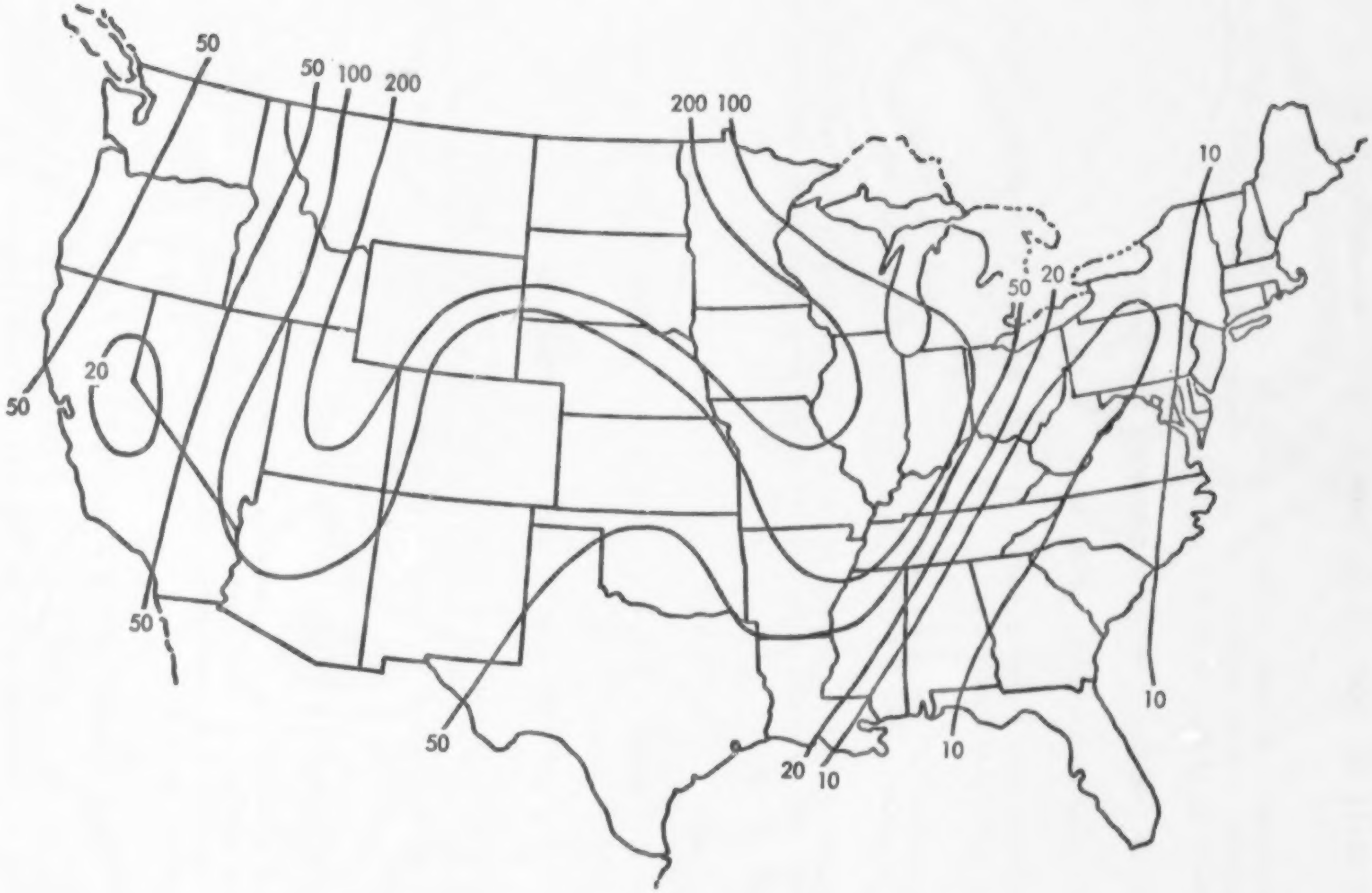
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Figure 7-1. Background alkalinity concentrations (ppm $CaCO_3$)

1. Estimate total number of potential mine drainage sources through review of state and local records, permits, etc., as indicated in Section 7.2.3.

2. Establish load index values for the following categories: active underground, active surface, inactive underground, and inactive surface, by procedures indicated in Section 7.2.3.

3. Sum up load index values established in Step 2.

4. Determine constant K_a from Table 7-1.

5. Multiply results generated in Steps 1, 3, and 4 to obtain value of statistical distribution term of the loading function.

6. Determine average annual runoff in area from standard runoff maps, e.g., U.S. Geological Survey's National Atlas, Plates 118 and 119.

7. Determine background alkalinity from iso-alkalinity map (Figure 7-1) or from other data deemed to reflect background alkalinity concentrations more adequately.

8. Determine proper constant K_b from Table 7-1.

9. Multiply values yielded by Steps 6, 7, and 8 to obtain background alkalinity term.

10. Subtract value obtained in Step 9 from that obtained in Step 5.

11. Multiply value obtained in Step 10 by the total number of mine drainage sources established in Step 1. This final step will yield the load of acid mine drainage being emitted from the mining region under consideration.

7.2.6 Examples of Option I Loading Function Utilization

The mine drainage loading function has been used to estimate loads emitted from two basins in Appalachia--West Branch Susquehanna, and Allegheny. These examples are presented to indicate how the mine drainage loading function can be used.

7.2.6.1 Case I: West Branch Susquehanna

Data Source - Federal Water Pollution Control Administration, Ohio Basin Region, U.S. Department of the Interior, "Stream Pollution by Coal Mine

Drainage in Appalachia," Attachment A to Appendix C of the Appalachian Regional Commission Report, Acid Mine Drainage in Appalachia, Washington, D.C. (1969).

Step 1. Number of mine sources N: 4,400
Number of draining sources: 967

Step 2. Load index values (Table 7-2):

Active underground: 19; 2% = 0.02
Active surface: 17; 2% = 0.02
Inactive underground: 630; 65% = 0.65
Inactive surface: 301; 31% = 0.31

Total: 967 100% = 1.00

Load indexes: $I_{AU} = 0.07$
$I_{AS} = 0.02$
$I_{IU} = 0.66$
$I_{IS} = 0.15$

Step 3. Load index summation total: 0.90

Step 4. Constant K_a from Table 7-1: 280

Step 5. Calculation of statistical distribution term: 280 x 0.9 = 252

Step 6. Average annual runoff Q(R): 20 in.

Step 7. Background alkalinity $C(Alk)_{BG}$ (from Figure 7-1): 10 ppm

Step 8. Constant K_b (from Table 7-1): 0.62

Step 9. Calculation of background alkalinity term: 0.62 x 20 x 10 = 124

Step 10. Subtract alkalinity term from statistical distribution term:
252 - 124 = 128

Step 11. Compute acid mine drainage load: 4,400 x 128 = 560,000 lb/day

Mine drainage (calculated) = 560,000 lb/day

Mine drainage (reported) = 500,000 lb/day

7.2.6.2 Case II: Allegheny River Basin (1966)

Data Sources - Appalachian Regional Commission Report, Acid Mine Drainage in Appalachia (1969); Tybout, R. A., "A Cost Benefit Analysis of Mine Drainage," paper presented before 2nd Symposium on Coal Mine Drainage Research, Pittsburgh, Pennsylvania, 14-15 May 1968; and U.S. Bureau of Mines, Minerals Yearbook, 1966, Washington, D.C. (1967).

Step 1. Number of mine sources N (Tybout): 6,626

Step 2. Load index values (Table 7-2):

Active underground: 228; 3% = 0.03
Active surface: 310; 5% = 0.05
Inactive underground: 2,350; 36% = 0.36
Inactive surface: 3,738; 56% = 0.56

Total: 6,626 100% = 1.00

Load indexes:

$I_{AU} = 0.10$
$I_{AS} = 0.08$
$I_{IU} = 0.51$
$I_{IS} = 0.24$

Step 3. Load index summation total: 0.93

Step 4. Constant K_a from Table 7-1: 280

Step 5. Calculation of statistical distribution term: 280 x 0.93 = 260

Step 6. Average annual runoff Q: 20 in.

Step 7. Background alkalinity $C(Alk)_{BG}$ (from Figure 7-1): 10 ppm

Step 8. Constant K_b (from Table 7-3): 0.62

Step 9. Calculation of background alkalinity term: 0.62 x 20 x 10 = 124

Step 10. Subtract alkalinity term from statistical distribution term: 260 - 124 = 136

Step 11. Compute acid mine drainage load: 6,626 x 136 = 900,000 lb/day

Mine drainage (calculated) = 900,000 lb/day

Mine drainage (reported) = 866,000 lb/day

7.3 OPTION II: STREAM TO SOURCE APPROACH

7.3.1 Loading Function and Information Needs

Since acid mine drainage is basically a discharge of sulfuric acid (and its reaction products), the presence of sulfate in stream water analyses is often a good indicator of nonpoint emissions from mine drainage sources. Thus, a comparison of sulfate levels detected in streams with that expected from natural background will yield an estimate of nonpoint emissions of mine drainage. The loading function can be expressed in two ways, depending upon the units of flow.

$$Y(AMD) = a \cdot A \cdot Q(R) \cdot \left[C(SO_4) - C(SO_4)_{BG} - C(SO_4)_{PT}\right] \qquad (7\text{-}8)$$

$$Y(AMD) = a \cdot Q(str) \cdot \left[C(SO_4) - C(SO_4)_{BG} - C(SO_4)_{PT}\right] \qquad (7\text{-}9)$$

where $Y(AMD)$ = yield of acid mine drainage, kg $CaCO_3$/day (lb $CaCO_3$/day)

A = area containing mine drainage sources, ha (acre)

$Q(R)$, $Q(str)$ = flow; Eq. (7-8) requires flow units $Q(R)$ as annual average runoff, in cm/year (in/year). Equation (7-9) requires flow units $Q(str)$ as streamflow in liters/sec (cfs).

$C(SO_4)$ = concentration of sulfate in surface waters, ppm

$C(SO_4)_{BG}$ = concentration of sulfate in surface waters attributable to background, ppm

$C(SO_4)_{PT}$ = concentration of sulfate in sources attributable to point sources, ppm

a = conversion constant for obtaining proper load

The two key elements of this loading function are in the conversion factor a and in the concentration of background sulfate $C(SO_4)_{BG}$. The value of a to be used in the loading function is determined by the units of flow. A table of a values is presented in Table 7-4. The values take into account the conversion of sulfate concentrations (in ppm) to their calcium carbonate equivalents (ppm as $CaCO_3$). This conversion is necessary in order to obtain load units of kilograms $CaCO_3$ per day (lb $CaCO_3$/day).

Table 7-4. CONVERSION FACTORS a TO BE USED FOR OPTION II MINE DRAINAGE LOADING FUNCTION

Sulfate concentration units	Units of flow Q	Units of area A	Value of a	Units of Y(AMD)
ppm	cm/year	ha	2.8×10^{-4}	kg $CaCO_3$/day
ppm	in/year	acre	6.4×10^{-4}	lb $CaCO_3$/day
ppm	liters/sec	-	0.090	kg $CaCO_3$/day
ppm	cfs	-	5.61	lb $CaCO_3$/day

The background levels of sulfate can be estimated through the use of an iso-sulfate background map presented in Figure 7-2. The region of interest is identified on the map, and sulfate levels estimated through the contours. If more specific data are available which are believed to describe background sulfate levels more adequately, then these data would be preferred to the use of Figure 7-2.

Other components of the loading function are obtained through standard sources. Sulfate concentration in streams, $C(SO_4)$, and streamflow, Q(str) , can be obtained from U.S. Geological Survey studies and from local water quality records. Annual average runoff can be estimated with the U.S. Geological Survey Surface Runoff Map, Plates 118 and 119, in the National Atlas. Sulfate contributions from point sources, $C(SO_4)_{PT}$, can be estimated from data contained in permit applications for point source discharges.

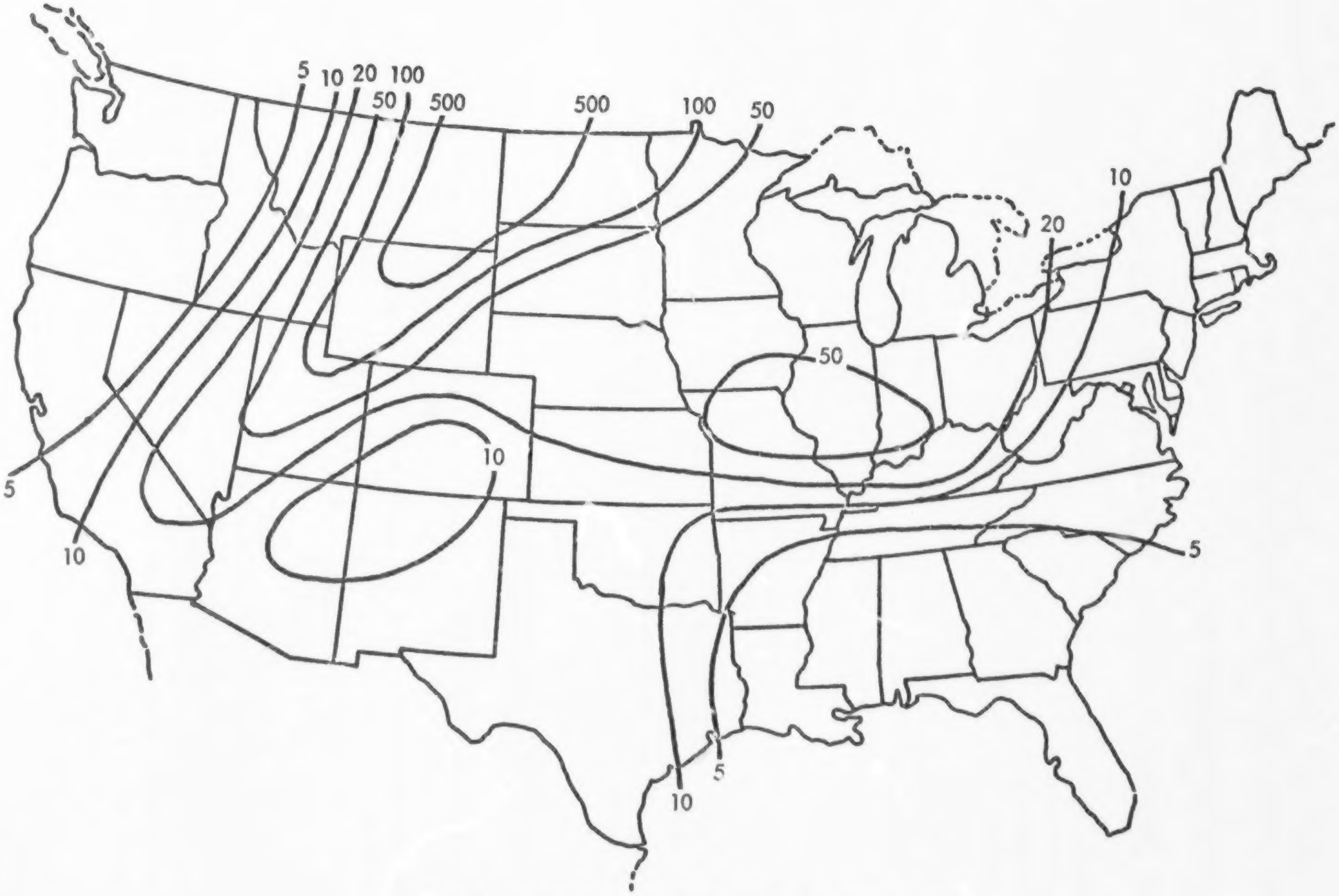
7.3.2 Procedure for Using Option II Mine Drainage Loading Function

The step-by-step procedure for using the Option II loading function is outlined below.

1. Obtain necessary water quality data, streamflow data, and areal data from U.S. Geological Survey records, local records, or other similar sources.

2. From these data establish appropriate values for A , Q(R) , and $C(SO_4)$.

3. Determine value for background sulfate, $C(SO_4)_{BG}$, using Figure 7-2, or from local water quality information thought to be more appropriate.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5
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10

Figure 7-2. Background sulfate concentrations (ppm)

4. Determine value of conversion constant a by means of Table 7-4.

5. Insert a , A , Q(R) , $C(SO_4)$ and $C(SO_4)_{BG}$ values established in the above steps into proper form of Option II loading function.

6. Compute mine drainage loads.

7.3.3 Example of Option II Loading Function for Mine Drainage

An example of how the Option II loading function can be used is summarized in Table 7-5. This table contains results for the Tioga and Juniata river basins in Appalachia obtained by the Option II loading function. The Option II estimates are within 80 to 110% of the reported loads.

The loading function works out well in these cases because mine drainages (and background) are the principal sources of sulfate in the area. If the loading function is applied to more highly industralized areas, e.g., the Anthracite Region of Appalachia, it tends to overpredict the nonpoint loads of mine drainage. In the industrial areas, point source discharges of sulfate report as nonpoint discharges within the context of the Option II method. Therefore, the Option II approach should be used mainly in rural areas. If amounts of the point source contributions of sulfate are known, however, they can be subtracted from estimates yielded by the Option II loading function. This procedure would ameliorate some of the deficiencies of using the stream to source approach in populated or industrialized areas.

7.4 ESTIMATED RANGE OF ACCURACY

A series of estimated value ranges for several acid mine drainage loads calculated using the Option I procedure are presented in Table 7-6. Two ranges are presented--one for Appalachia, and one for regions other than Appalachia. As can be seen by the ranges, the loading function is more accurate when applied to coal mining in Appalachia than it is when used in other parts of the country.

One major source of error in the Option I loading function lies in the number of mine drainage sources in the area being considered with the loading function. If not enough sources are available in an area, it is likely that their distribution of loads will not meet that of the "typical" mine from which the loading function was developed. This problem will most often be encountered in regions outside of Appalachia where mining activity density (number of mines in the area being considered) is small.

Table 7-5. ESTIMATED MINE DRAINAGE EMISSIONS FROM TIOGA AND JANIATA RIVER BASINS USING OPTION II LOADING FUNCTION

Essential information: $Y(AMD) = a \cdot Q(str) \cdot \left[C(SO_4) - C(SO_4)_{BG} - C(SO_4)_{PT}\right]$

$a = 5.61$

$C(SO_4)_{BG} = 10$ ppm

Basin	Flow at confluence (cfs)	Sulfate concentration at confluence (ppm)	Total sulfate load (lb $CaCO_3$/day)	Background sulfate load (lb $CaCO_3$/day)	Calculated mine drainage load (lb $CaCO_3$/day)	Reported mine drainage load[a] (lb $CaCO_3$/day)
Tioga	25	150	21,000	1,400	19,600	24,100
Juniata	150	60	50,500	8,400	42,100	37,900

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[a] Federal Water Pollution Control Administration, Ohio Basin Region, U.S. Department of the Interior, "Stream Pollution by Coal Mine Drainage in Appalachia," Attachment A to Appendix C of the Appalachian Regional Commission Report, Acid Mine Drainage in Appalachia, Washington, D.C. (1969).

Table 7-6. ESTIMATED RANGE OF LOADS FOR OPTION I (SOURCE TO STREAM) ACID MINE DRAINAGE LOADING FUNCTIONS

Number of mine drainage sources	Calculated load (kg/day)	Probable range of loads (kg/day) Appalachia	Probable range of loads (kg/day) Other than Appalachia
> 1,000	1,000	200-5,000	a/
	10,000	5,000-20,000	a/
	100,000	80,000-120,000	a/
100-1,000	500	0-3,000	0-5,000
	5,000	1,000-20,000	500-50,000
	50,000	20,000-80,000	10,000-100,000
< 100	100	0-1,000	0-2,000
	1,000	0-10,000	0-20,000
	10,000	1,000-30,000	500-50,000

a/ Areal density of mining activities outside of Appalachia is less than 1,000 mines per total area considered.

Another source of uncertainty lies in the choice of the constants K_a and K_b in the loading function. The calculated loads in Table 7-6 assume $K_a = 130$ and $K_b = 0.54$ as indicated in Table 7-1. However, a range of values is provided for both K_a and K_b in Table 7-1 and the user is at liberty to select values of these constants which best represent his area. The larger ranges in areas outside Appalachia as indicated in Table 7-6 reflect a higher degree of uncertainty in proper choices of K_a and K_b in the loading function.

A third source of error in the Option I function is found in the estimation of background neutralization capacity. The neutralization capacity of background will vary widely throughout the area in which mine drainage sources are located. This variation in background alkalinity, together with the relatively large areas that need to be considered in order to have enough sources for the statistical distribution, is probably the biggest source of error in the loading function.

The estimates in Table 7-6 suggest that more uncertainty is to be expected with small loads than with large loads. This greater uncertainty is due to the subtraction steps in the Option I procedure. The nearer in magnitude the statistical distribution and background alkalinity terms, the greater the potential error in the calculated value. Indeed, there may be instances where calculated acid mine drainage emissions will be zero (or a negative value), when in fact acid mine drainage is present. These occurrences are most probable in areas having high background alkalinities such as found in the Midwest.

The Option II stream to source approach for acid mine drainage depends strictly upon measured sulfate levels in streams compared to estimated sulfate levels in background. Estimated ranges of acid mine drainage loads are presented in Table 7.7. An area of 1 million hectares (4,000 sq miles) has been used to differentiate between larger and small areas in Table 7-7. The range of loads arising from smaller areas are somewhat broader on a percentage basis than are the loads from the larger areas. The differences in breadth reflect the fewer number of sources in the smaller area, as well as a higher degree of uncertainty in background levels.

Table 7-7. ESTIMATED RANGE OF LOADS FOR OPTION II (STREAM TO SOURCE) ACID MINE DRAINAGE LOADING FUNCTIONS

Area containing mining sources (ha)	Calculated load (kg/day)	Probable range of loads (kg/day)
< 1,000,000	1,000	200-10,000
	10,000	5,000-30,000
> 1,000,000	1,000	500-3,000
	10,000	6,000-20,000
	100,000	70,000-150,000

In addition to area differences, Table 7-7 also indicates a wider range for small total loads than for large total loads. These differences are due to uncertainties in the difference between total sulfate and background sulfate, i.e., the $[C(SO_4) - C(SO_4)_{BG}]$ term. The larger loads thus reflect a larger "net" sulfate attributable to acid mine drainage. A larger net value is inherently more accurate than a small net value. Thus, larger loads calculated by the Option II procedure are more accurate than smaller loads calculated in the same manner.

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1. Environmental Quality Systems, Inc., "Determination of Estimated Mean Mine Water Quantity and Quality from Imperfect Data and Historical Records," Report to the Appalachian Regional Commission, January 1973.

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SECTION 8.0

HEAVY METALS AND RADIOACTIVITY

8.1 INTRODUCTION

Two options are presented for estimating nonpoint loads of heavy metals or radioactivity. The estimation procedures for both heavy metals and radioactivity are identical, except that input data for heavy metals require concentration reported in parts per billion, while input data for radioactivity require units of picocuries per liter. The two options are:

Option I - Source to Stream Approach: A summation of loads emitted by known sources in the area under consideration. These sources represent, in most cases, emissions from abandoned mining sites and from their associated processing operations such as tailings piles. This approach will be sufficient in those areas where the nonpoint sources have been identified. Since all mines do not produce drainage to transport heavy metals or radioactivity, the contribution of the nondraining mines to the total load will be zero. In many other cases, drainage from many inactive mining sites will be negligible when compared to the few major sources. Contribution to the total load from many minor sources may be insignificant compared to the load from the few major sources.

Option II - Stream to Source Approach: An estimation of loads obtained by difference between total load and estimated background load. This option should be used where specific sources of heavy metal or radioactivity have not been identified or characterized. Since most heavy metals and radioactive nuclides tend to precipitate within a short distance after their discharge into surface waters, the possibility exists that heavy metals or radioactive contents of stream water samples do not accurately reflect the quantity of materials actually delivered to the stream by nonpoint sources. This problem can be overcome by using water quality data sampled at points known to be in close proximity to the nonpoint sources, even though precise locations of nonpoint sources are unknown.

In addition to the above methods, the special case of heavy metals associated with sediment loads is discussed in Section 8.5. The U.S. Geological Survey has reported results of an extensive sampling and analysis program in which heavy metal contents of surficial soils in the United States were determined.[1/] This study indicates that heavy metals in sediment constitute a significant nonpoint load in terms of quantity. However, the impact of the heavy metal load on surface water quality is much less severe. The method described in Section 8.5 "piggy-backs" the heavy metal concentration of soils onto the sediment loading function (Eq. 3-1, Section 3.2.2) in order to estimate sediment-borne heavy metal nonpoint loads arising from the various sources of sediment emissions.

8.2 OPTION I: SOURCE TO STREAM APPROACH

8.2.1 Information Requirements for Loading Value Equation

The loading value equations for estimating heavy metal or radioactivity loads emitted by nonpoint sources using the source to stream approach are:

$$Y(HM) = a \sum_n Q_n \cdot C(HM)_n \qquad (8\text{-}1)$$

$$Y(RAD) = a \sum_n Q_n \cdot C(RAD)_n \qquad (8\text{-}2)$$

where $Y(HM)$ = yield of heavy metal from a given area, kg/day (lb/day)

$Y(RAD)$ = yield of radioactivity from a given area, picocuries/day

$C(HM)_n$ = concentration of heavy metals emitted from nth source, µg/liter (ppb)

$C(RAD)_n$ = concentration of radioactivity emitted from the nth source, picocuries/liter

Q_n = flow transporting pollutant from the nth source, liters/sec (cfs)

a = conversion factor needed to obtain proper units of load (see Table 8-1)

Flow (Q) and concentration (C) information is obtained from data gathered from recent nonpoint monitoring studies, or from permit application records. The nonpoint sources emitting heavy metals or radioactivity are likely to be abandoned or inactive mining sites, milling and ore beneficiation sites, and associated waste rock dumps and tailings ponds. If such data are not available, it may be necessary to use the Option II approach rather than Option I.

8.2.2 Procedure for Using Option I Loading Value Equation

The step-by-step procedure for using Option I for heavy metals and radioactivity loads is:

Table 8-1. CONVERSION FACTORS a TO BE USED FOR OPTION I LOADING VALUE EQUATIONS

Constituent	Concentration units	Units of flow "Q"a/	Value of "a"	Units of "Y load"
Heavy metals	ppb	ℓ/sec	8.64×10^{-5}	kg/day
		cfs	5.39×10^{-3}	lb/day
Radioactivity	picocuries/ℓ	ℓ/sec	8.64×10^{-4}	picocuries/day
		cfs	2.45×10^{-6}	picocuries/day

---

a/ Flow data may be obtained from U.S. Geological Survey Records, STORET data, U.S. Army Corps of Engineer records, or other records available at local levels.

1. Obtain data for composition and flow of drainage from individual nonpoint sources.

2. If heavy metal concentration data are reported in units other than parts per billion (or µg/liter), convert data to parts per billion units. Conversion of parts per million to parts per billion is accomplished by:

$$ppb = 1,000 \times ppm$$

If radioactivity units are reported in units other than picocuries per liter, convert data to proper units.

3. If flow units in raw data are reported as gallon per minute, gallon per day, etc., convert flows to liters per second (cfs).

4. Add concentrations of heavy metals or radioactivities to obtain total concentrations. Heavy metals include all metallic constituents except: sodium, potassium, calcium, magnesium, and aluminum. The metalloids arsenic and antimony should be counted as heavy metals.

The total heavy metals may be separated into three subcategories if desired:

Category A - iron + manganese;
Category B - arsenic + copper + lead + zinc; and
Category C - remaining heavy metals.

5. Multiply flows and concentrations for each individual site.

6. Add up all computed values obtained in Step 5.

7. Choose proper conversion constant from Table 8-1 based upon units of flow, Q , established in Step 3.

8. Compute load by multiplying the sum obtained in Step 6 by conversion constant identified in Step 7.

8.2.3 Example of Option I Source to Stream Approach

The Option I approach has been applied to heavy metals emissions from abandoned mine sites in the Coeur d'Alene River Valley in Idaho. The computations are summarized in Table 8-2.

Table 8-2. NONPOINT HEAVY METAL EMISSIONS ESTIMATES FROM SOME INACTIVE MINES IN THE COEUR d'ALENE VALLEY, IDAHO USING OPTION I METHODS[a]

Mine and nearest town	Flow (gpm)	Flow (ℓ/sec)	Iron + manganese (ppb)	Load iron + manganese (kg/day)	Arsenic + copper + lead + zinc (ppb)	Load arsenic + copper + lead + zinc (kg/day)	Miscellaneous heavy metals (ppb)	Load miscellaneous heavy metals (kg/day)	Total load heavy metals (kg/day)
1. Adair, Manhattan Creek	20	1.3	159	0.02	15	0.002	4	0.005	0.027
2. Aldegulch, Murray	small	~ 0.3	1,300	0.03	562	0.02	8	0.002	0.052
3. Bullion, Wallace	small	~ 0.3	208	0.005	15	0.0004	4	0.0001	0.0055
4. California Gulch, Nine Mile Creek	small	~ 0.3	1,783	0.05	133	0.003	11	0.0003	0.0533
5. Duncan Gulch	small	~ 0.3	3,447	0.09	109	0.003	32	0.0008	0.0938
6. Galconda, Mullan	20	1.3	5,450	0.6	41	0.005	10	0.001	0.606
7. Monitor, Wallace	small	~ 0.3	1,560	0.04	11,342	0.3	49	0.001	0.341
8. Murray, Murray	small	~ 0.3	1,382	0.04	109	0.003	4	0.0001	0.0431
9. Placer Gulch, Wallace	5	0.3	200	0.005	25	0.0006	6	0.0002	0.0058
10. Silver Beaver, Wallace	10	0.6	3,855	0.2	64	0.003	5	0.0003	0.2033
11. Snowstorm Peak, Mullan	30	1.9	172	0.03	256	0.04	5	0.0008	0.0708
12. Sunset Peak, Wallace	small	~ 0.3	390	0.01	212	0.006	67	0.002	0.018
Total load for non-point sources				1.12		0.386		0.0136	1.5196

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[a] Sceva, J. E., "Water Quality Considerations for The Metal Mining Industry in the Pacific Northwest," Draft Report, Region X, U.S. Environmental Protection Agency, Seattle, Washington (1973).

The information in Table 8-2 points out the major weakness of the Option I approach--it is not known whether all nonpoint sources are accounted for. It is believed, however, that major contributors are known, and that this sum represents a good "average" for heavy metal contributions in the region.

8.3 OPTION II: STREAM TO SOURCE APPROACH

8.3.1 Loading Value Equations and Information Needs

Four loading value equations for estimating heavy metal or radioactivity loads emitted by nonpoint sources using the stream to source approach can be used. These equations are:

Case 1 $$Y(HM) = a \cdot A \cdot Q(R) \cdot [C(HM) - C(HM)_{BG}] \quad (8\text{-}3)$$

Case 2 $$Y(HM) = a \cdot Q(str) \cdot [C(HM) - C(HM)_{BG}] \quad (8\text{-}4)$$

Case 3 $$Y(RAD) = a \cdot A \cdot Q(R) \cdot [C(RAD) - C(RAD)_{BG}] \quad (8\text{-}5)$$

Case 4 $$Y(RAD) = a \cdot Q(str) \cdot [C(RAD) - C(RAD)_{BG}] \quad (8\text{-}6)$$

where $Y(HM)$ = yield of heavy metal from a given area, kg/day (lb/day)

$Y(RAD)$ = yield of radioactivity from a given area, picocuries/day

$C(HM)$ = concentration of total heavy metals emitted from nonpoint sources, ppb (μg/liter)

$C(HM)_{BG}$ = concentration of total heavy metals emitted from background, ppb (μg/liter)

$C(RAD)$ = concentration of radioactivity emitted from nonpoint sources, picocuries/liter

$C(RAD)_{BG}$ = concentration of radioactivity emitted from background sources, picocuries/liter

A = area containing nonpoint sources, ha (acres)

$Q(R)$ = flow as average annual runoff, cm (in.)

$Q(str)$ = flow as streamflow, liters/sec (cfs)

a = conversion factor needed to obtain proper units of load (see Table 8-3)

The four cases are differentiated by the type of flow data available to the user. Cases 1 and 3 require average annual runoff in centimeters per year (in/year) obtainable from standard runoff maps, e.g., U.S. Geological Survey's National Atlas, Plates 118 and 119. Cases 2 and 4 can use measured streamflow values measured in volume per time unit (i.e., liters/sec or cfs). The values for particular streams are available in U.S. Geological Survey records, STORET data, and U.S. Army Corps of Engineers streamflow records.

In areas of highly variable flow (such as mountainous regions), the use of annual average runoff values (Cases 1 and 3) is recommended unless precise knowledge of streamflow at the sampling site is known. If annual average runoff is used, it is desirable in some cases to not consider the area (A) factor if the areal extent drained above the sampling point is not known accurately. If so done for Cases 1 and 3, the units of load would become kilograms per hectare per day (lb/acre/day).

On the other hand, if good streamflow and concentration data are available to the user, he should use the Cases 2 or 4 loading value equations to estimate heavy metal or radioactivity emissions.

8.3.2 Estimation of Heavy Metal and Radioactivity Emissions from Background

A key part of the Option II approach is the estimation of heavy metals and radioactivity emissions from background. A series of maps have been developed for estimating background concentrations of heavy metals and radioactivity. These maps are:

Figure 8-1. Background total heavy metals (ppb)
Figure 8-2. Background iron + manganese (ppb)
Figure 8-3. Background arsenic + copper + lead + zinc (ppb)
Figure 8-4. Background miscellaneous heavy metals (ppb)
Figure 8-5. Background radioactivity (picocuries/liter)
Figure 8-6. Background alpha radioactivity (picocuries/liter)
Figure 8-7. Background beta radioactivity (picocuries/liter)

Table 8-3. CONVERSION FACTORS "a" TO BE USED FOR OPTION II LOADING VALUE EQUATION

	Constituent	Concentration units	Units of flow "Q"	Units of area "A"	Value of "a"	Units of Y(HM) or Y(RAD)
Case 1	Heavy metals	ppb	cm/yr	ha	2.7×10^{-7}	kg/day or kg/ha/day[a]
			in/yr	ac	6.2×10^{-7}	lb/day or lb/ac/day[a]
Case 2	Heavy metals	ppb	ℓ/sec		8.64×10^{-5}	kg/day
			cfs		5.39×10^{-3}	lb/day
Case 3	Radioactivity	picocuries/ℓ	cm/yr	ha	270	picocuries/day or picocuries/ha/day[a]
			in/yr	ac	280	picocuries/day or picocuries/ac/day[a]
Case 4	Radioactivity	picocuries/ℓ	ℓ/sec		8.64×10^{-4}	picocuries/day
			cfs		2.45×10^{-6}	picocuries/day

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[a] Units of Y(HM) or Y(RAD) obtained if Area (A) is not used in loading value equation.

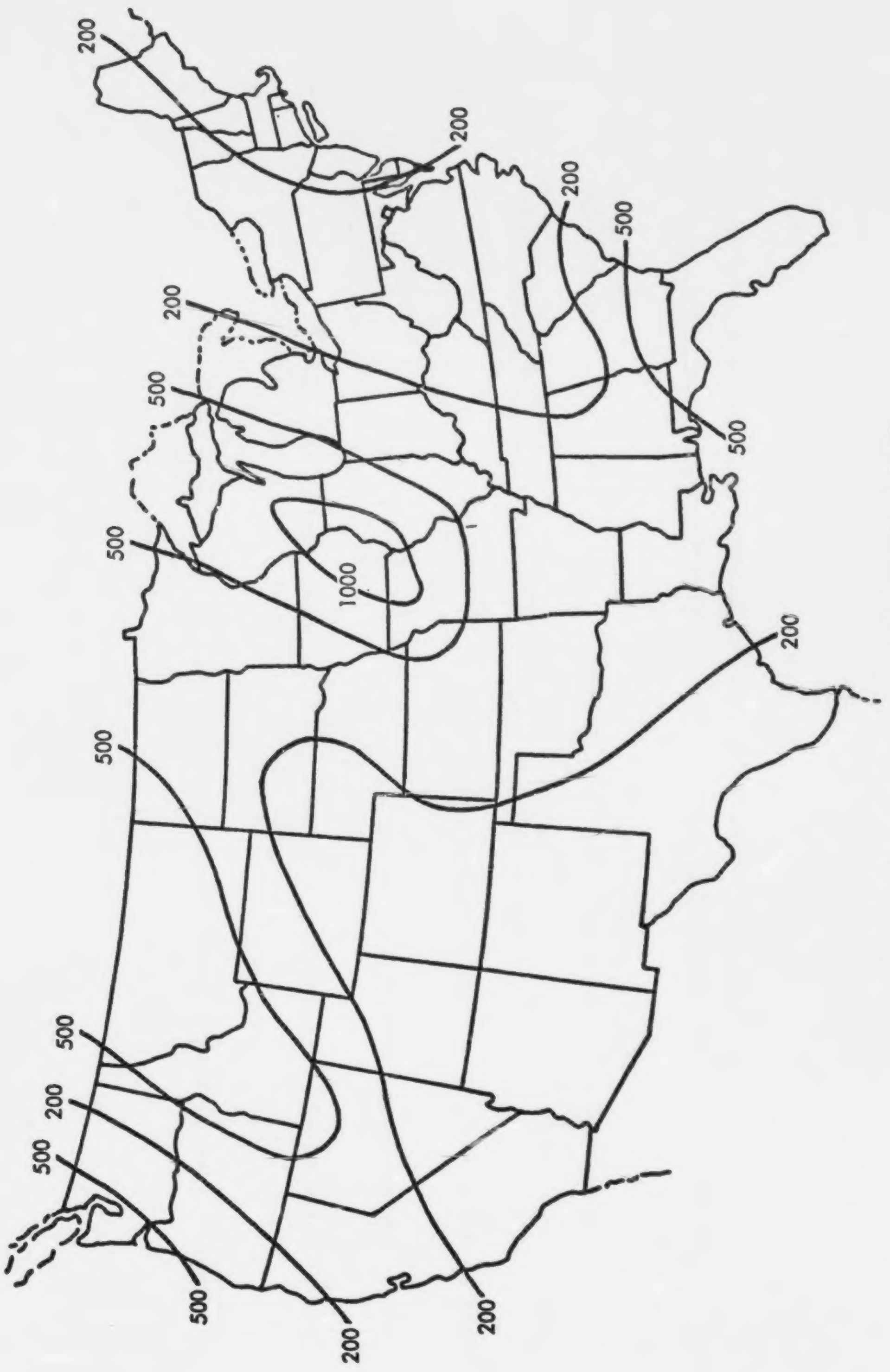
200
200
200
500
500
200
500
500
1000
200
500
500
200
500
500
200
200

Figure 8-1. Background total heavy metals (ppb)

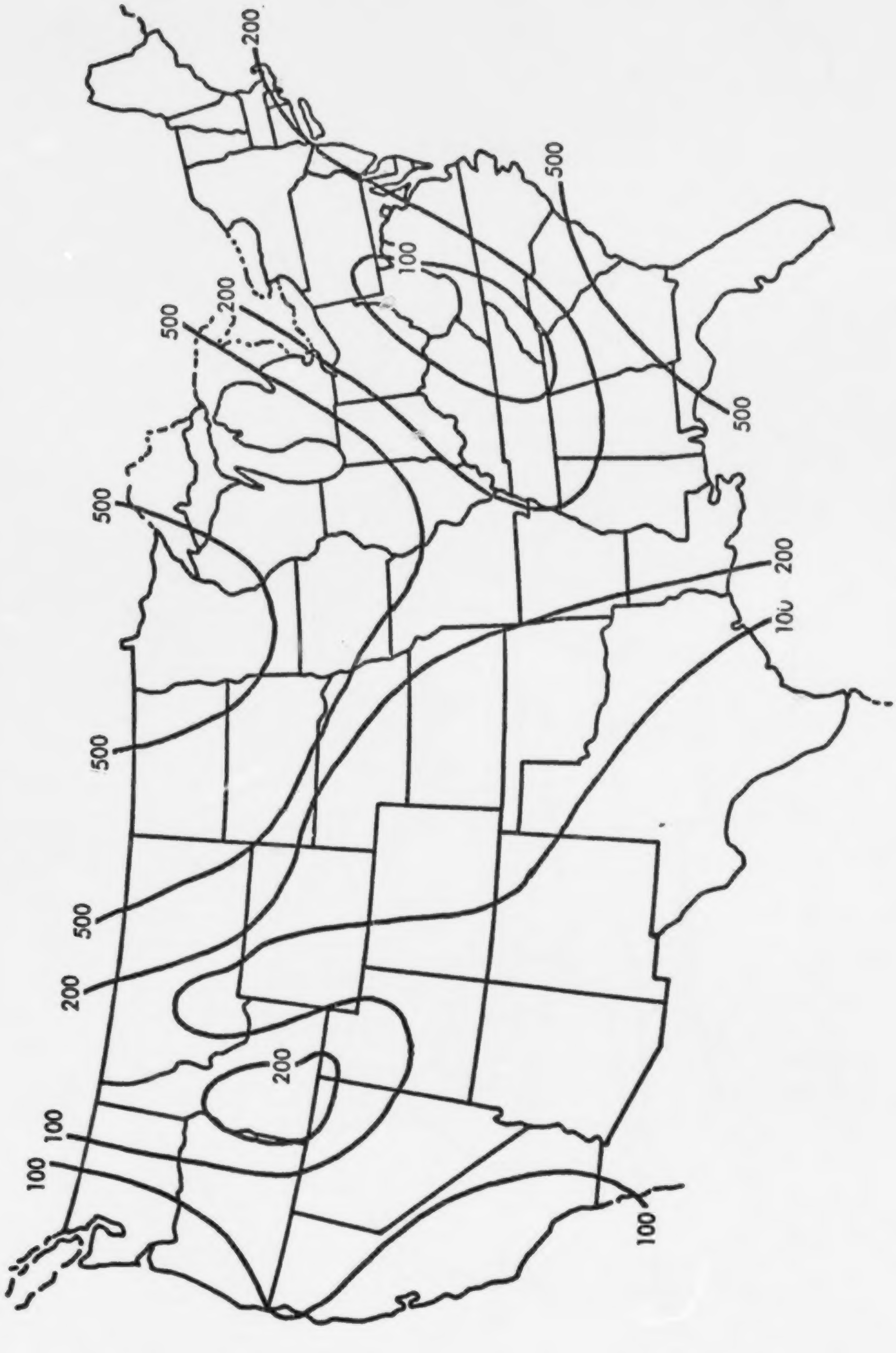
200
500
100
200
500
500
500
500
200
100
500
200
200
100
100
100

Figure 8-2. Background iron + manganese (ppb)

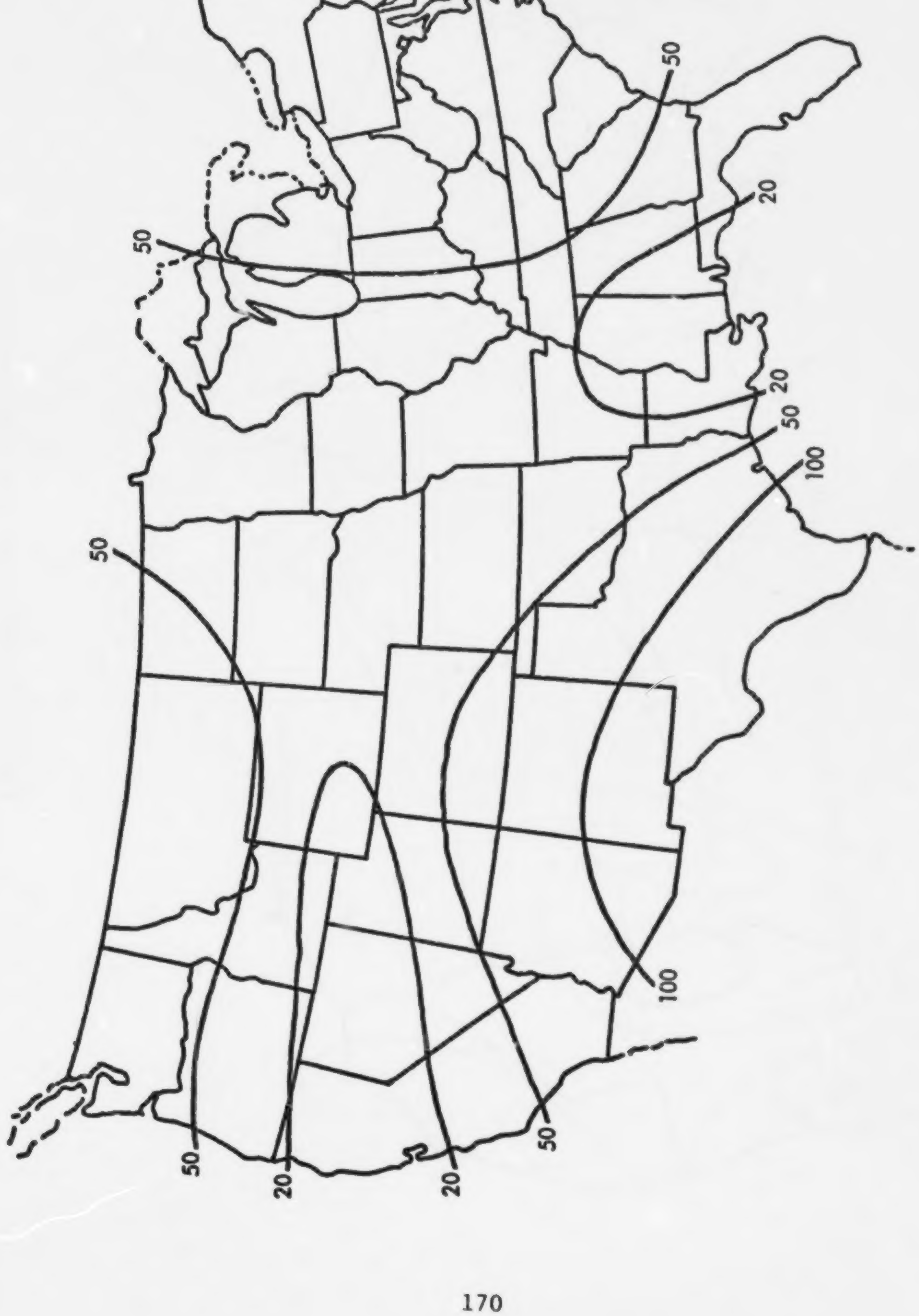
50
50
50
20
20
50
100
50
50
20
20
50
100

Figure 8-3. Background aresenic + copper + lead + zinc (ppb)

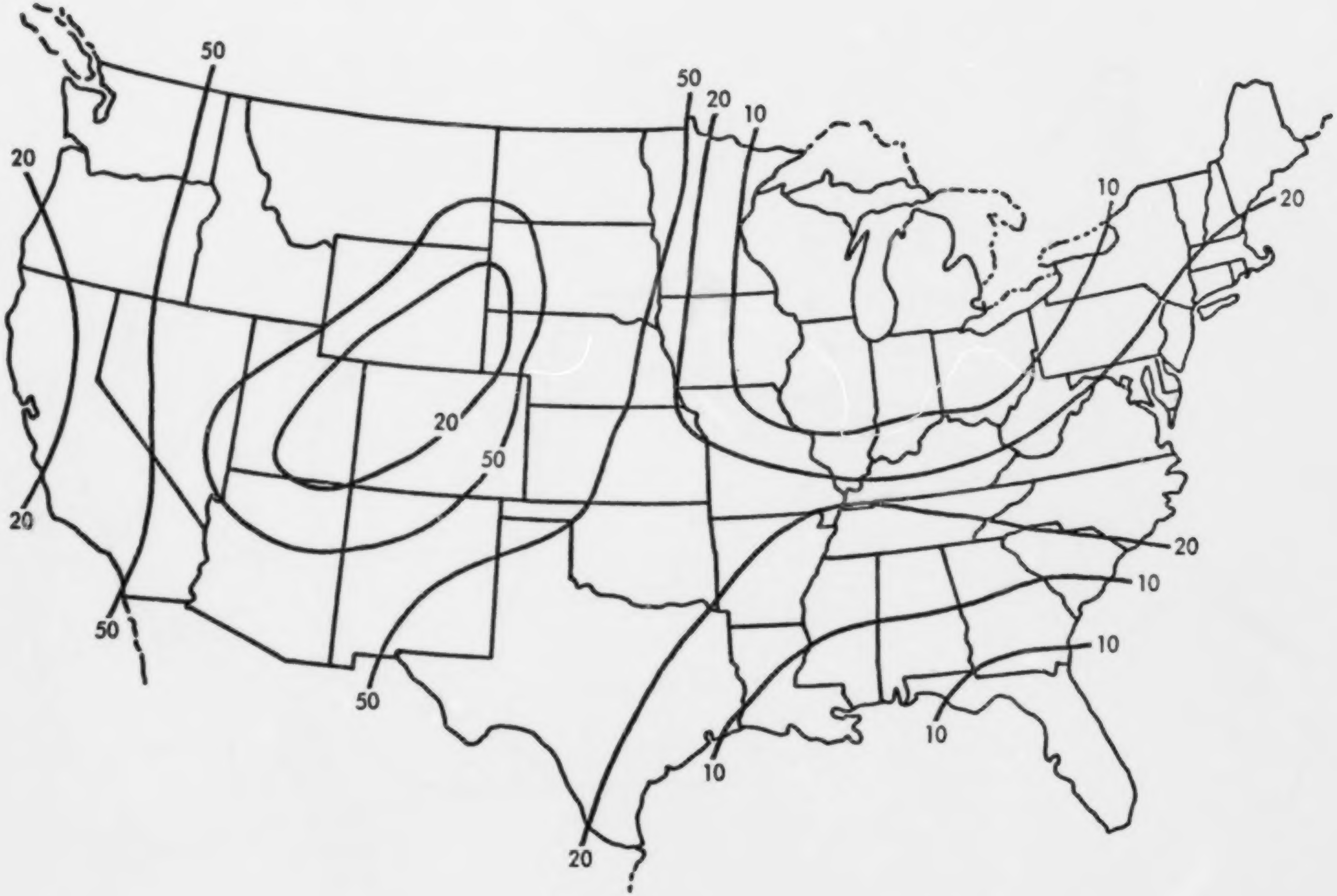
50
50
20
10
10
20
20
20
20
50
20
10
10
50
50
10
20

Figure 8-4. Background miscellaneous heavy metals (ppb)

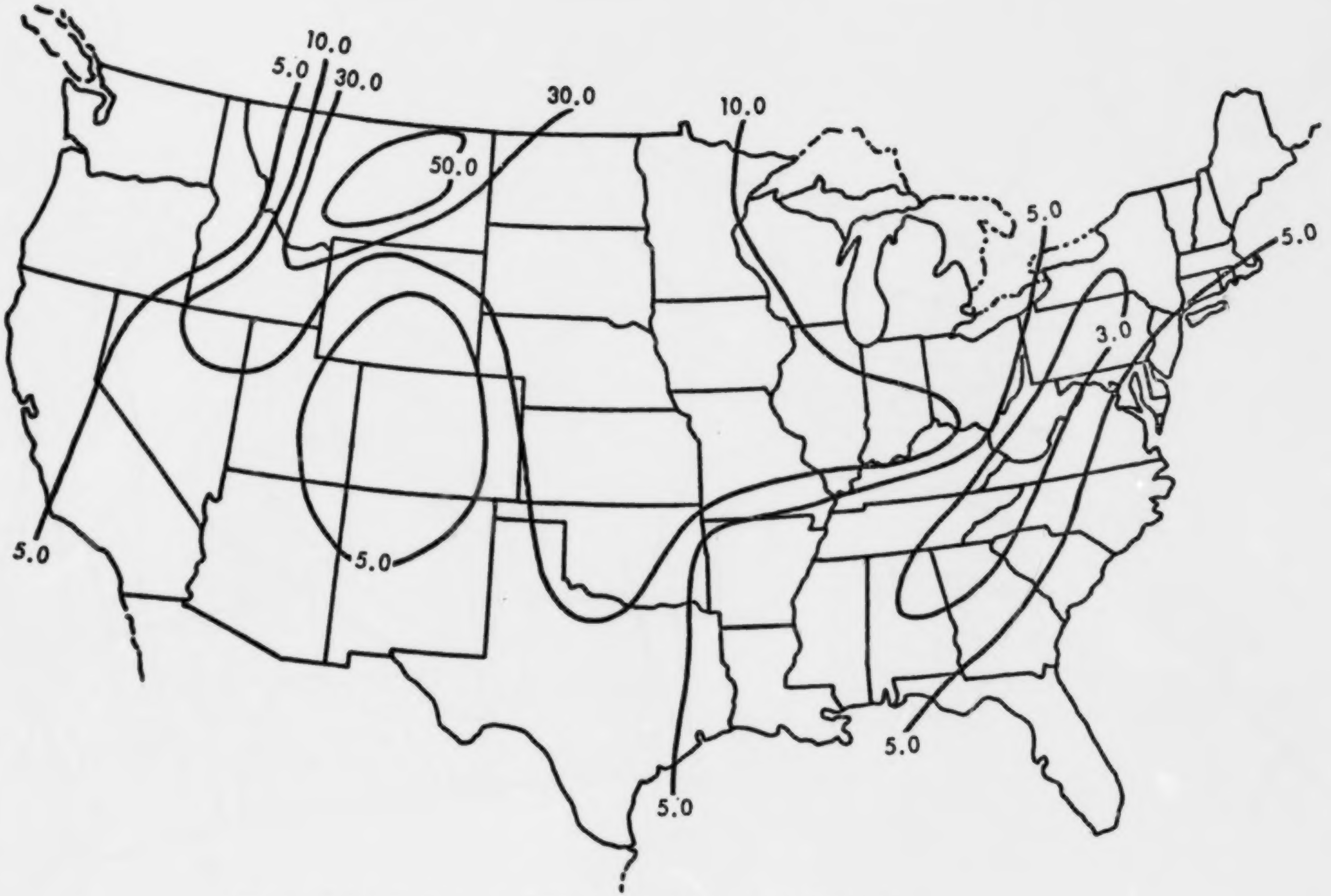
10.0
5.0
30.0
30.0
50.0
10.0
5.0
5.0
3.0
5.0
5.0
5.0
5.0

Figure 8-5. Background radioactivity (picocuries/liter)

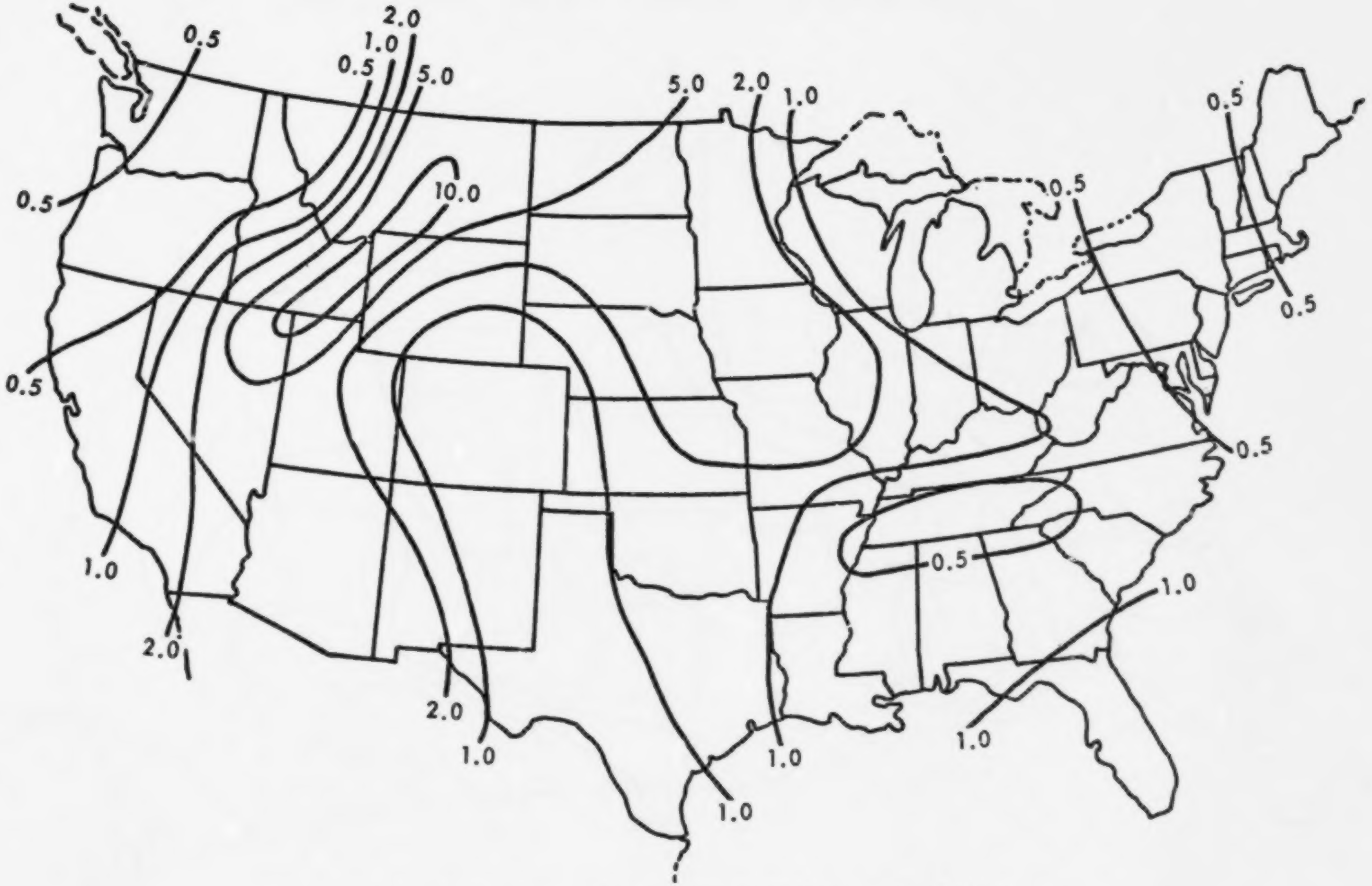
0.5
2.0
1.0
0.5
5.0
5.0
2.0
1.0
0.5
0.5
0.5
10.0
0.5
0.5
0.5
0.5
1.0
2.0
0.5
1.0
2.0
1.0
1.0
1.0
1.0
1.0

Figure 8-6. Background alpha radioactivity (picocuries/liter)

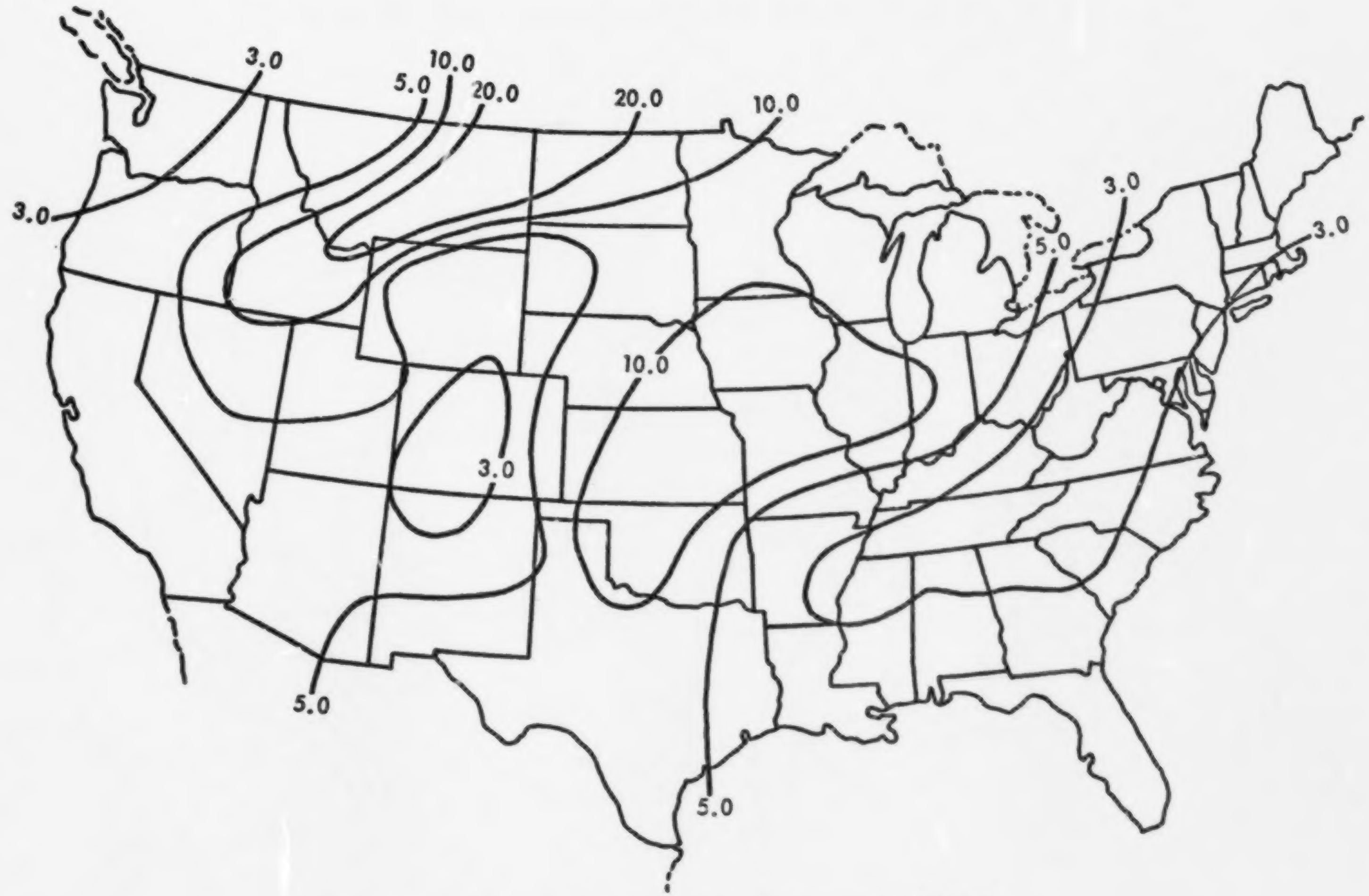
3.0
10.0
5.0
20.0
20.0
10.0
3.0
3.0
5.0
3.0
10.0
3.0
5.0
5.0

Figure 8-7. Background beta radioactivity (picocuries/liter)

If other sources are not available, these maps should be used to estimate background concentrations of needed constituents.

8.3.3 Procedure for Using Option II Loading Value Equations

The step-by-step procedure for using the Option II approach for estimating heavy metal and radioactivity emissions is:

1. Obtain data for heavy metal and radioactivity concentrations from a selected number of monitoring stations. The data should include concentration and flow information.

2. Obtain data for heavy metal and radioactivity concentrations in background. These data may be local data deemed proper by the user, or from the maps (Figures 8-1 through 8-7) presented earlier.

3. If flow data are not available with concentration data, estimate flow as annual average runoff from standard U.S. Geological Survey Runoff Maps.

4. After proper flow and concentration data have been acquired, choose the proper case and determine "a" value from Table 8-3.

5. Sum up heavy metal concentrations to obtain total heavy metals. The total heavy metal may be broken into three subtotals: iron + manganese; arsenic + copper + lead + zinc; and miscellaneous heavy metals. The heavy metal constituents to be considered in the summing process have been identified in Section 8.2.2, Step No. 4, of this report.

6. If flow data are limited to average annual runoff, and if good areal data are not known, do not consider area (A) factor in loading value equation. This aspect will yield results in kilogram per hectare per day (lb/acre/day).

7. After data have been obtained and processed using the above steps, insert into proper loading value equation and compute loads.

8.3.4 Example of Option II Stream to Source Approach

The Option II approach has been used to estimate heavy metal loading from nonpoint sources in Clear Creek County, Colorado. Results of this estimation are presented in Table 8-4. These computations have used the Case 1 loading value equation, i.e., flow is estimated by average annual runoff. In addition, areal data were insufficient to estimate loads. Thus, loads are reported as kilogram per hectare per day.

Table 8-4. HEAVY METAL POLLUTANT EMISSIONS FROM SEVERAL STREAMS IN CLEAR CREEK COUNTY, COLORADO[a]

	Iron + manganese		Arsenic + copper + lead + zinc		Miscellaneous heavy metals	
	Concentration (ppb)	Load (kg/ha/day)	Concentration (ppb)	Load (kg/ha/day)	Concentration (ppb)	Load (kg/ha/day)
Case 1 approach: QF = 25 cm/yr; $a = 2.7 \times 10^{-7}$ A factors are unknown, loads reported in kg/ha/yr						
Background: Chicago Creek above South Chicago Creek near Idaho Springs, Colorado	70		15		5	
Nonpoint Pollutant Emissions:						
1. WF Clear Creek above Woods Creek at Berthoud Falls, Colorado	5,910	0.04	222	0.001	10	c/
2. Woods Creek at mouth at Berthoud Falls, Colorado	4,800	0.03	1,811	0.01	26,000[b]	0.2
3. WF Clear Creek near Empire, Colorado	1,320	0.01	72	c/	6	c/
4. Fall River near Idaho Springs, Colorado	30	c/	58	c/	1	c/
5. Virginia Canyon Creek at mouth at Idaho Springs, Colorado	85,000	0.6	10,000	0.07	1,700	0.01
6. Soda Creek at mouth at Idaho Springs, Colorado	89	c/	91	c/	1	c/
7. Clear Creek above North Clear Creek near Hidden Valley, Colorado	1,720	0.01	632	0.004	13	c/
8. Clear Creek above Quayle Creek at Bakerville, Colorado	136	c/	47	c/	0	c/
9. Clear Creek above South Clear Creek at Georgetown, Colorado	63	c/	884	0.006	3	c/
10. South Clear Creek at mouth at Georgetown, Colorado	17	c/	5	c/	0	c/
11. Leavenworth Creek at mouth near Georgetown, Colorado	24	c/	143	0.001	0	c/
12. Clear Creek above WF Clear Creek near Empire, Colorado	105	c/	578	0.004	1	c/
13. Ute Creek at mouth near Idaho Springs, Colorado	56	c/	88	0.001	5	c/
14. Chicago Creek above Spring Creek at Idaho Springs, Colorado	160	0.001	75	c/	0	c/
15. Lion Creek at mouth at Empire, Colorado	18,000	0.1	2,000	0.01	226	0.002
16. Clear Creek above Chicago Creek at Idaho Springs, Colorado	650	0.004	385	0.002	7	c/
17. Clear Creek above STP Outfall at Idaho Springs, Colorado	2,020	0.01	823	0.005	12	c/
18. Clear Creek below Sawmill Gulch near Hidden Valley, Colorado	1,860	0.01	618	0.004	9	c/

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a/ Wentz, D. A., "Effect of Mine Drainage on the Quality of Streams in Colorado," Colorado Water Resources Circular No. 21, Colorado Water Conservation Board, Denver, Colorado (1974).

b/ All molybdenum.

c/ Less than 0.001 kg/ha/day (1.0 g/ha/day).

In order to obtain actual loads, drainage areas represented by each sampling station should be known. Estimation of the areas might be accomplished by studying U.S. Geological Survey topographic maps. Once areas are estimated, they should be multiplied by the proper loading rates and summed to obtain estimates for the total load arising from the nonpoint sources.

8.4 EXPECTED ACCURACY OF METHODS

In the case of the Option I approach where individual sources are summed, the accuracy will depend upon the variability of the emission loads from each source. However, as more and more sources are included in the summation, the more accurate will be the estimate. This increased accuracy will arise because of the greater number of points forming the statistical distribution of sources. Option I also assumes that the principal sources of heavy metal and radioactivity emissions are known for the area under consideration. Thus, the use of Option I should be restricted to only those persons with knowledge of the area. An estimate of the accuracy of Option I methods for heavy metals is presented in Table 8-5 for several calculated loads. The accuracy for radioactivity would be expected to fall into the same percentage ranges.

Option II is inherently less accurate than Option I, since it depends upon a good estimate of background emissions of heavy metals and radioactivity, and involves a comparison of these components actually found with the background estimates. Background heavy metals are particularly difficult to estimate, since wide variations in concentrations are noted and emissions are nonuniform throughout the country. Because specific sources are not involved, heavy metal and radioactivity loads are considered to be diffuse and emitted uniformly from all land area considered when Option II is used. Thus, use of the Option II method is more accurate with larger areas. Accuracy ranges are narrowed further when large loads are emitted rather than small loads, since Option II involves comparison of total loads with background loads. The greater the difference between total and background levels, the less will be the error introduced by the subtraction operation. An estimate of expected accuracy for heavy metals emissions using Option II is presented in Table 8-6.

Table 8-5. EXPECTED ACCURACY OF OPTION I (SOURCE TO STREAM) METHOD FOR HEAVY METALS

Number of sources	Calculated load (kg/day)	Probable range of loads (kg/day)
10	0.1	0.01-1.0
	1	0.5-5
50	1	0.7-3
	5	2-10
	10	5-15
100	1	0.8-2
	5	3-8
	10	7-15
	20	17-25

Table 8-6. EXPECTED ACCURACY OF OPTION II (STREAM TO SOURCE) METHOD FOR HEAVY METALS

Area containing sources (ha)	Calculated load (kg/ha/year)	Probable range of loads (kg/ha/year)
< 1,000,000	1	0.2-15
	10	3-30
> 1,000,000	1	0.4-10
	10	5-20

8.5 HEAVY METALS ATTACHED TO SEDIMENT

8.5.1 Loading Function

The largest single nonpoint heavy metal load into surface waters will be that which is carried by sediment. The U.S. Geological Survey has undertaken an in-depth study[1] to determine the elemental composition of surficial materials in the United States. Soil samples were collected from 863 sites throughout the 48 conterminous states and analyzed for 44 different elements. Of these 44 elements, 36 are heavy metals as defined earlier, i.e., metallic or metalloid elements with atomic number greater than 20. Sediment arising from various sources throughout the country will carry these elements into surface waters. Thus, the amount of heavy metal delivered with the sediment is directly proportional to the sediment load.

The loading function is:

$$Y(HM)_S = a \cdot C_S(HM) \cdot Y(S)_E \qquad (8\text{-}7)$$

where $Y(HM)_S$ = yield of heavy metals in sediment, kg/day (lb/day)

$C_S(HM)$ = concentration of heavy metals in eroded soil, ppm

$Y(S)_E$ = sediment yield metric tons/year (tons/year)

a = conversion factor to obtain proper units of load. If $Y(S)_E$ is expressed in metric tons/year, $a = 2.74 \times 10^{-6}$; if $Y(S)_E$ is expressed as English tons/year, $a = 5.48 \times 10^{-6}$.

The loading function assumes that there is no enrichment (or loss) of heavy metals in the eroded soil. One would not expect to have either enrichment or loss of heavy metals in the sediment, since they are tied up in insoluble forms in the soils.

The loading function (Eq. (8-7)) is apt to yield very large values for heavy metal emissions. The metals are an integral part of the soil-sediment matrix, and most are sparingly soluble in water. The fraction of the load which solubilizes in surface waters is usually very small, and the impact on water quality is thus very much less than one would calculate on the basis of a total load discharged to the stream.

8.5.2 Information Needs

Two basic pieces of information are needed to estimate emissions of heavy metals associated with sediment: the amount of sediment produced, $Y(S)_E$; and the amount of heavy metals in the eroded soils, $C_S(HM)$. The value of $Y(S)_E$ is determined using sediment loading procedures (USLE Eq. (3-1)) described in Section 3.0. The value of $C_S(HM)$ can be determined from the data collected by the U.S. Geological Survey in their report concerning elemental composition of surficial materials,[1/] or from other data available locally.

The average concentrations and ranges of the various heavy metals in surficial materials obtained from the 863 sampling stations are presented in Table 8-7. In addition to the arithmetic averages, the geometric means (another form of "averaging") have also been included on a national basis, as well as an Eastern and Western areal basis. The line separating East from West is the 97th meridian.

In many cases, the elements were found to be in concentrations less than the detection limits of the analytical methods employed by the USGS. The concentrations of these elements are shown in Table 8-7 to be less than the detection limits, and no average can be presented. The metals which fall in this category are arsenic, cadmium, germanium, gold, hafnium, indium, platinum, palladium, rhenium, tantalum, tellurium, thallium, thorium, and uranium. Many of these elements are known, from other studies, to be present in soils.

For those elements which were generally found to be above detection limits, the concentration at each sampling site has been plotted and mapped in the U.S. Geological Survey report.[1/] Specific heavy metals in specific areas can be estimated from these maps. Thus, the USGS report can serve as a basic reference for U.S. data concerning heavy metals in sediment.

8.5.3 Relationship Between Heavy Metals in Soils and in Surface Waters

As can be seen in Table 8-7, the predominant heavy metal in surficial material is iron. The metal having next greatest abundance is titanium. On the average, these two elements constitute about 93% of all heavy metals in soils. The remaining 7% is made up of many elements, ranked in the following order: manganese, barium, strontium, zirconium, cerium, vanadium, zinc, chromium, neodymium, lanthanium, yttrium, copper, lead, nickel, gallium, niobium, cobalt, and scandium.

The high percentage of titanium in the soils is not reflected in surface waters. As has been shown in Figure 8-1 and 8-2, iron and manganese constitute the major portion of heavy metals in surface waters. Thus, one concludes that the solubility mechanisms of manganese and titanium in soils differ substantially. From the surface water quality data, it would also seem that the zinc, copper and lead constituents of eroded soils are relatively mobile in aqueous systems.

On a total load basis, the heavy metals emitted through the sediment route are much greater than the load detected in surface waters. A comparison of heavy metals loads in natural background indicates that the surface water load is approximately 1% of the load coming via the sediment route. Most of the metals which are detected in the streams consist of iron, manganese, arsenic, copper, lead and zinc, whereas those in the sediment are primarily iron and titanium. Thus, the impact of heavy metals on the quality of surface waters is probably much smaller than the absolute loads of sediment indicate. However, the differences in solubility and mobility mechanisms of individual metal components are important for establishing impacts of specific species.

8.5.4 Reliability of the Procedure

The reliability of estimating heavy metal loads through the procedure discussed above is a function of three factors: (a) the accuracy of the sediment loads delivered to the stream (Table 3-10); (b) the accuracy of the heavy metal concentration measurements in the soil; and (c) the variability of heavy metal concentrations in the eroded soils. Of these three factors, the one concerning variability of heavy metal content will be the most uncertain. The estimated ranges of values for several heavy metal loads is presented in Table 8-8.

Table 8-7. HEAVY METAL CONCENTRATIONS IN SURFICIAL MATERIALS IN THE UNITED STATES[a]

Element	Arithmetic analysis		Geometric means		
	Average (ppm)	Range (ppm)	Conterminous U.S. (ppm)	West of 97th meridian (ppm)	East of 97th meridian (ppm)
Arsenic	--	< 1,000	--	--	--
Barium	554	15-5,000	430	560	300
Cadmium	--	< 20	--	--	--
Cerium	86	< 150-300	75	74	78
Chromium	53	1-1,500	37	38	36
Cobalt	10	< 3-70	7	8	7
Copper	25	< 1-300	18	21	14
Iron	25,000	100-100,000	18,000	20,000	15,000
Gallium	19	< 5-70	14	18	10
Germanium	--	< 10	--	--	--
Gold	--	< 20	--	--	--
Hafnium	--	< 100	--	--	--
Indium	--	< 10	--	--	--
Lanthanum	41	< 30-200	34	35	33
Lead	20	< 10-700	16	18	14
Manganese	560	< 1-7,000	340	389	285
Molybdenum	< 3	< 3-7	--	--	--
Neodymium	45	< 70-300	39	36	44
Nickel	20	< 5-700	14	16	13
Niobium	13	< 10-100	12	11	13
Palladium	--	< 1	--	--	--
Platinum	--	< 30	--	--	--
Rhenium	--	< 30	--	--	--

Table 8-7 (concluded)

Element	Arithmetic analysis		Geometric means		
	Average (ppm)	Range (ppm)	Conterminous U.S. (ppm)	West of 97th meridian (ppm)	East of 97th meridian (ppm)
Scandium	10	< 5-50	8	9	7
Strontium	240	< 5-3,000	120	210	51
Tantalum	--	< 200	--	--	--
Tellurium	--	< 2,000	--	--	--
Thallium	--	< 50	--	--	--
Thorium	--	< 200	--	--	--
Titanium	3,000	300-15,000	2,500	2,100	3,000
Uranium	--	< 500	--	--	--
Vanadium	76	< 7-500	56	66	46
Ytterbium	4	< 1-50	3	3	3
Yttrium	29	< 10-200	24	25	23
Zinc	54	< 25-2,000	44	51	36
Zirconium	240	< 10-2,000	200	170	250
Total	30,099		21,991	23,858	19,263

Note: "--" indicates all analyses showed element to be below detectable limits.

a/ Reference 1.

Table 8-8. EXPECTED ACCURACY OF HEAVY METAL LOADS DELIVERED WITH SEDIMENT

Calculated load (kg/day)	Probable range of loads (kg/day)
0.1	0.001-1.5
1	0.05-10
10	1-30
100	30-200

Reference

1. Shacklette, H. T., J. C. Hamilton, J. G. Boernagen, and J. M. Bowles, "Elemental Composition of Surficial Materials in the Conterminous United States," U.S. Geological Survey Proffessional Paper 574-D, Washington, D.C. (1971).

SECTION 9.0

URBAN AND RELATED SOURCES

This section describes pollutant loading functions for developed urban areas and related sources. In the subsections that follow, the sources and types of pollutants and factors affecting pollutant generation, as well as loading functions and relevant data, are presented in the following sequence: urban runoff, Section 9.1; traffic related pollutants, Section 9.2; and street and highway deicing salts, Section 9.3.

Discussion in this section pertains only to established areas. Loading functions for areas under construction are presented in Section 3.0, "Sediment Loading Functions," of this Handbook.

9.1 POLLUTANTS FROM URBAN RUNOFF

From established urban areas, stormwater may pick up various wastes ranging from settled dust and ash to debris coming directly from man himself. The quantities of solids from urban nonpoint sources are quite significant in quantity. Fly ash and dust from industrial processes such as steel mills, cement manufacturing, and certain chemical processes are known to be profuse. Dusts from the burning of organic fuels are a significant factor, and solids in sizable quantities also result from off-street mud, automotive exhaust, organic debris from tree leaves and grass trimmings, and discarded litter.

In this Handbook, the nonpoint pollutant loading function for urban areas is formulated from pollutant loading values obtained in a recent URS study[1/] for the U.S. Environmental Protection Agency. In that study URS reviewed a large number of published reports, extracted and statistically analyzed data, and presented average solid loading values and chemical and biological composition of solids.

In analyses of urban runoff data, URS assumed that only the runoff from street surfaces contributed to urban nonpoint pollution. The resulting loading values for solid wastes are given in terms of pounds per curb-mile per day. The user should note that these values represent contributions from both street and nonstreet surfaces.

Data developed in the URS study include nationwide means, as well as a more detailed breakdown of data into major source categories, of solids loading rates and pollutant composition of street solids. Table 9-1 reproduces, from the URS report, data which are divided into 13 subsets among three major source categories including climate, land use, and average daily traffic. These data are different from the whole set means which are given in the last column of the table, at the 80% confidence level. Whenever the mean of any parameter (solid loading rates or composition) in any subset differs significantly from the mean of the set of all data, that number may be substituted for the mean of the set of all data. Table 9-1 also gives the percent standard error of the mean which indicates the degree of confidence that may be placed on the mean.

Table 9-2 presents the means and standard deviations of concentrations of mercury and several pesticides, which resulted from a set of data that were characterized as "very small and unreliable."

9.1.1 Loading Functions

The functions which make use of solid accumulation rates and solid composition and provide for quantitative assessment of pollutant loadings in urban runoff within a specified urban area are given as follows:

Loading functions for solids

$$Y(S)_u = L(S)_u \cdot L_{st} \qquad (9\text{-}1)$$

where $Y(S)_u$ = daily total solids loading, kg/day (lb/day)

$L(S)_u$ = daily solids loading rates, kg/curb-km/day (lb/curb-mile/day)

L_{st} = street curb-length (approximately 2.0 x street length), curb-km (curb-miles).

Table 9-1. SOLID LOADING RATES AND COMPOSITIONS--NATIONWIDE MEANS AND SUBSTITUTIONS OF THE NATIONWIDE MEANS AT 80% CONFIDENCE LEVEL* 1/

		lbs/curb mi/day	Concentrations in micrograms per gram of dry solid																No./gram	
	Category	Loading	BOD_5	COD	OPO_4	TPO_4	NO_3	NH_4	OrgN	Cd	Cr	Cu	Fe	Pb	Mn	Ni	Sr	Zn	TCOLI+	FCOLI+
Climate	Northeast	291_e							$5,970_e$	2.6_b	139_b		$17,700_b$	870_c	363_a	21_c	27_b	360_b		$4.4E5_e$
	Southeast	103_b	$29,100_b$		$2,240_a$				$1,970_a$			137_b		$1,370_b$		21_b	28_b			$7.0E4_d$
	Southwest	30_c			470_b						241_a	78_a		$2,320_b$		57_b	15_a		$3.7E6_d$·	
	Northwest	30_c									246_a		$34,500_b$	$2,600_b$			10_c	480_a	$6.8E5_f$	$1.1E4_f$
Land Use	Open space																			
	Residential		$14,000_b$	$32,000_b$	850_b		350_c		$1,800_a$			93_a		$1,430_b$		28_b				
	Commercial	74_e	$58,700_c$	$269,000_c$	$2,250_c$		$1,580_c$		$6,430_a$			133_b		$3,440_b$		48_b		520_b		
	Light industry																			
	Heavy industry										278_b		$28,600_b$	$1,160_c$	370_b				$8.2E5_e$	
Average Daily Traffic No./day	< 500													$1,210_d$				252_b		$6.9E4_f$
	500 - 5,000		$9,500_e$	$83,000_e$	741_d·		419_b						$18,900_a$	$1,060_c$		17_d	34_c			$3.4E5_d$
	5,000 - 15,000																18_a			
	> 15,000	82_d													357_a				$3.8E5_e$	
	All data	156_b	$19,900_b$	$140,000_b$	$1,280_b$	$2,930_c$	804_b	$2,640_c$	$2,950_b$	3.4_a	211_a	104_a	$22,000_a$	$1,810_a$	418_a	35_a	21_a	370_a	$2.5E6_c$	$1.7E5_b$

---

*Only those subset means are shown which differ from the mean of the set of all data at the 80-percent confidence level (Student t ≥ 1.39, Degrees of Freedom ≥ 10). Total number of permitted substitutions = 103. Percent Standard Error of the Mean Subscripting Code: a = 0 - 9, b = 10 - 19, c = 20 - 29, d = 30 - 39, e = 40 - 49, f = 50 - 63.

+Coliform counts are expressed in computer notation, i.e., E5 = 10^5.

Table 9-2. MEAN CONCENTRATIONS OF MERCURY AND CHLORINATED HYDROCARBONS IN STREET DIRT FROM NINE U.S. CITIES[1]

	Concentrations in micrograms per kilogram of dry solid								
	Hg	Endrin	Dieldrin	PCB	Methoxy-chlor	DDT	Lindane	Methyl parathion	DDD
Mean	83	0.2	28	770	500	76	2.9	2	82
Standard deviation	111	-	28	770	1,050	118	7.1	-	78

Loading functions for other pollutants

$$Y(i)_u = a \cdot Y(S)_u \cdot C(i)_u \qquad (9\text{-}2)$$

where $Y(i)_u$ = daily total loading of pollutant i, kg/day (lb/day); MPN($\times 10^{-6}$) per day for total coliform and fecal coliform

a = conversion factor
= 10^{-6} (metric and English)

$Y(S)_u$ = daily total loading of solids, kg/day (lb/day), calculated in Eq. (9-1)

$C(i)_u$ = concentration of pollutant i in solids, ug/g; MPN/g for total coliform and fecal coliform

Equations (9-1) and (9-2), along with solid loading values and compositions in Tables 9-1 to 9-2, provide the means to assess daily average pollutant loadings from urban areas.

It is important to note that pollutant loadings so calculated are street surface loadings rather than loadings at outfalls to the receiving waters. The transport of storm runoff in sewers and removal of pollutants in some treatment systems would reduce pollutant loads to some extent. Such effects are not included in loading factors suggested in Tables 9-1 and 9-2. Furthermore, the methodology presented above does not reflect the effect of housekeeping practices in the urban area. Good housekeeping practices such as cleaning of street solids by sweeping, and the use of catchment basins to remove solids and organic matter, will reduce pollutant loads from streets to receiving waters.2/

9.1.2 Procedure for Loading Calculations

Data in Tables 9-1 and 9-2 represent two options as well as two levels of accuracy for a user to assess pollutant loadings from a given urban area. Application of the "subset" data may result in higher accuracy, but require more data and more computation effort, than if "nationwide means" are used.

Option I - In this option the user will use nationwide means presented in Tables 9-1 and 9-2. Proceed as follows:

1. Determine solid loading rate and solid composition from tables.

2. Determine street length (include that of primary and secondary streets but not driveways, alleys, or parking lots).

3. Calculate daily solid loading using Eq. (9-1).

4. Calculate daily loading of other pollutants using Eq. (9-2).

Option II - In this option the user will make use of data presented for source categories in Table 9-1. Steps needed for loading calculations are:

1. Characterize the study urban area. When applicable, the entire area should be divided into individual homogeneous sections with unique characteristics. Each individual section is then defined as a subarea (e.g., residential area).

2. Determine street length in each subarea.

3. Enter the Table 9-1 at the line labeled "All Data."

4. Select a category of climate, land use, or average daily traffic, which best applies to an area and move upward to the line of data to the right of the category heading.

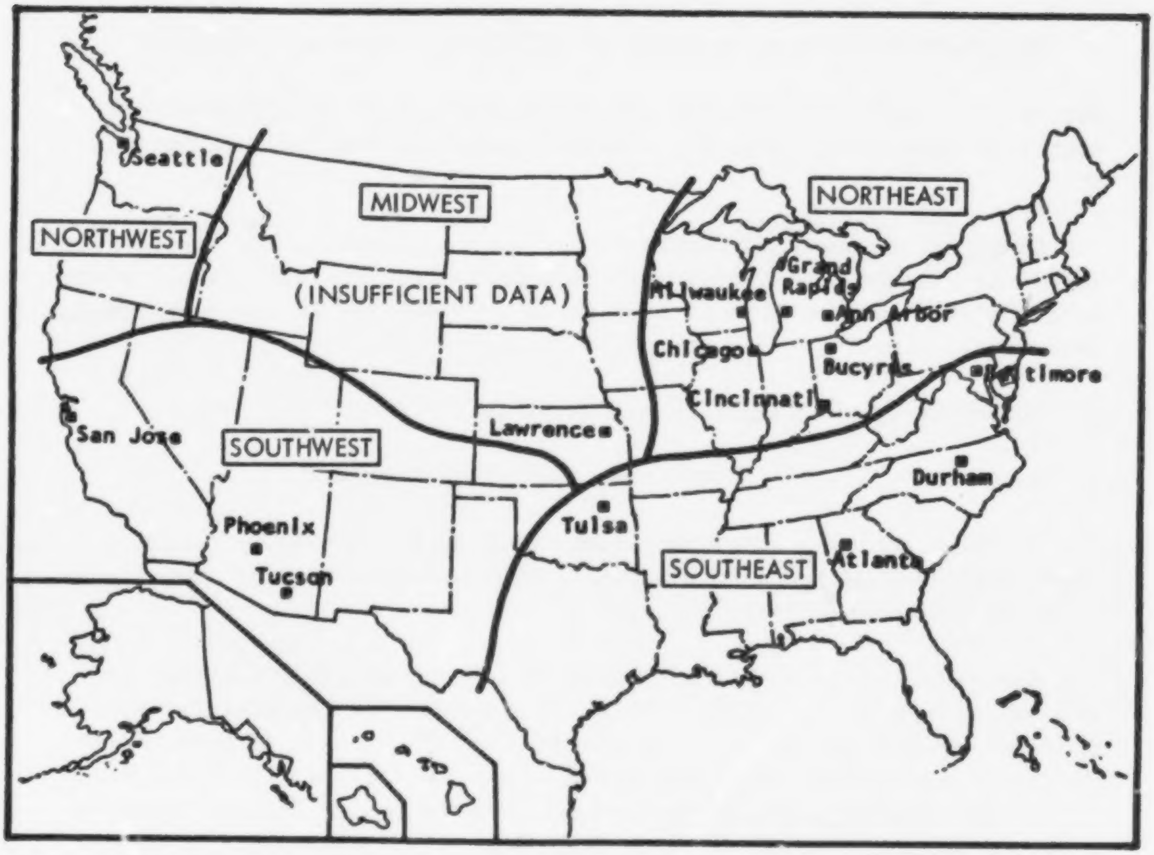
5. Substitute those values available in the row selected for the corresponding values in the row labeled "All Data." In choosing the substitute loading factors, the following priority sequence of source categories is suggested: (a) climate; (b) land use; (c) average daily traffic. The climatic zones of the U.S. delineated by the URS are shown in Figure 9-1. Caution: it is not permissible to use more than one row of substitutions at a time, i.e., to use a BOD value for land use and COD for climate in order to form a new row of loading rate and composition data. It is both proper and useful, however, to repeat the above process to obtain several new rows of data to present a range of composition and loading rates. Use data from Table 9-2, if desired.

6. Repeat Steps 4 and 5 for all subareas.

7. Use Eq. (9-1) to calculate total solid loading in a subarea.

8. Use solid loading (Step 7), Eq. (9-2) and selected composition data to calculate total loading of other pollutants in a subarea.

9. Sum up loadings of subareas to obtain the loading of the entire study area.



Seattle
NORTHWEST
MIDWEST
(INSUFFICIENT DATA)
NORTHEAST
Milwaukee
Grand Rapids
Ann Arbor
Chicago
Bucyrus
Baltimore
Cincinnati
San Jose
SOUTHWEST
Lawrence
Durham
Phoenix
Tulsa
Tucson
SOUTHEAST
Atlanta

Figure 9-1. Climate zone for the cities from which data are available and used in the URS study[1]

The calculation procedure delineated for Option I and Option II above is illustrated in Section 9.1.4.

Option III - In this option, the user will make use of site specific data.

The recent URS study has assembled all presently available data on the rates of accumulation of solids and on the concentrations of various pollutant constituents in those solids that collect on street surfaces. These data are probably adequate for most urban planning operations. The user, however, may alternatively replace these loading factors by site specific data to obtain better prediction.

If site specific data are lacking, users are encouraged to conduct sampling and analytical programs of their own. The data from site specific tests, if handled properly, may be used in analyzing the area's runoff problems instead of using values given in this Handbook. This would be desirable in most instances, especially in areas or under specific conditions that were not documented in the URS study.

Recommended procedures for conducting site specific tests are given in Appendix B of the URS Report.1/

With the lack of site specific data, the user may wish to examine the available published data for source and reliability. The user is referred to Appendix A of the URS Report1/ for description of available data sources, as well as procedures for processing these data.

9.1.3 Street Length and Land Use Data for Urban Areas

Data on street length - Street length data are available from local public works departments or street departments. They can also be obtained by measurement on aerial photographs.

Survey statistics for the U.S. indicate that street surfaces occupy on the average about one-sixth of the urban area.3/ The American Public Works Association4/ recently developed a regression between curb length of urban area versus population density. Data from many cities across the country were used. The resulting regression equation is:

$$CL = 413.11 - (352.66)(0.839)^{PD} \qquad (9\text{-}3)$$

where CL = curb length density, ft/acre

PD = population density, number/acre

The correlation coefficient for the equation is 0.72. The regression curve is shown in Figure 9-2.

Curb length can be estimated if street surface acreage is known. Table 9-3 presents equivalent curb length per unit area of street surface, suggested by URS.[1/] However, if actual values are known, it is best to use known values.

Land use data - The following references provide survey data and analysis results relative to land uses in major urban areas of the U.S.:

Bartholomew, H., Land Use in American Cities, Harvard University Press, Cambridge, Massachusetts (1955).

Niedercorn, J. H., and E. F. R. Hearle, "Recent Land-Use Trends in Forty-Eight Large American Cities," The RAND Corporation, Santa Monica, California, Memorandum RM-3664-FF, June 1963.

Manuel, A. D., R. H. Gustafson, and R. B. Welch, "Three Land Research Studies," National Commission on Urban Problems, Research Report No. 12, Washington, D.C. (1968).

The American Public Works Association[4/] estimated land consumption rates for various land uses in American cities, shown in Table 9-4. These rates can be used to estimate acreages in different land uses if the number of population is known.

9.1.4 Example

The study area is a 250-acre urban watershed in Atlanta, Georgia. The area is mainly residential and has 17 curb-miles of primary and secondary streets. Predict the average daily loadings of BOD and lead in runoff from the entire area.

Option I - Use nationwide means of solid loading rate and compositions given in Table 9-1.

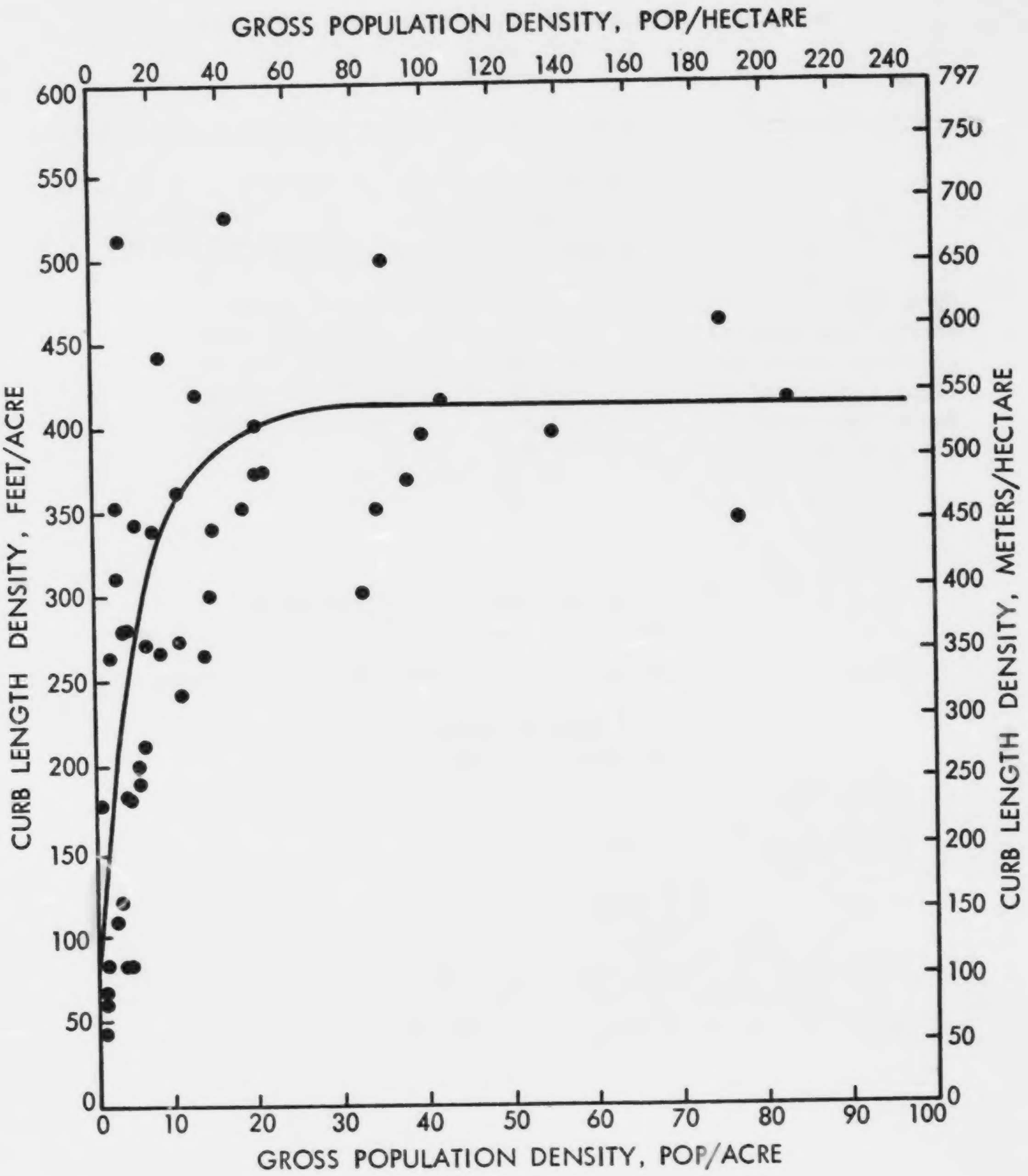


Figure 9-2. Correlation between population density and curb length density.[4]

Table 9-3. EQUIVALENT CURB-LENGTH PER UNIT AREA OF STREET SURFACE, ARRANGED BY LAND USE TYPES[1]

	Equivalent curb-km per hectare of street surface	Equivalent curb-miles per acre of street surface
Open land	2.11	0.53
General residential	2.15	0.54
General commercial	1.63	0.41
Light industrial	1.71	0.43
Heavy industrial	1.59	0.40
All land use types	1.83	0.46

Table 9-4. GENERAL LAND CONSUMPTION RATES FOR VARIOUS LAND USES[4]

	Land consumption (acres/capita)		
Land use	≤ 100,000 Population	> 100,000 Population	> 250,000 Population
Residential	0.1049	0.0714	0.0585
Commercial	0.0101	0.0084	0.0073
Industrial	0.0177	0.0083	0.0077
Park	0.0146	0.0093	0.0078

Calculate solid loading -

$L(S)_u$ = 156 lb/curb-mile/day

$Y(S)_u = 156 \cdot 17 = 2{,}652$ lb/day

Calculate BOD and Pb loadings -

$C(BOD)_u = 19{,}900 \cdot 10^{-6}$ lb/lb solid

$C(Pb)_u = 1{,}810 \cdot 10^{-6}$ lb/lb solid

$Y(BOD)_u = 2{,}652 \cdot 19{,}900 \cdot 10^{-6} = 52.8$ lb/day

$Y(Pb)_u = 2{,}652 \cdot 1{,}810 \cdot 10^{-6} = 4.8$ lb/day

Option II - Use substitutions at 80% confidence level.

Atlanta is in the southeast. Move upward in Table 9-1 to southeast climate category. A loading substitution is available. Make all available substitutions into the row labeled "All Data." The new row has, among others:

Solid loading rate, $L(S)_u$ = 103 lb/curb-mile/day

BOD concentration, $C(BOD)_u = 19{,}900 \cdot 10^{-6}$ lb/lb solid

Pb concentration, $C(Pb)_u = 1{,}370 \cdot 10^{-6}$ lb/lb solid

Calculate solid loading -

$Y(S)_u = 103 \cdot 17 = 1{,}751$ lb/day

Calculate BOD and Pb loadings -

$Y(BOD)_u = 1{,}751 \cdot 19{,}900 \cdot 10^{-6} = 34.8$ lb/day

$Y(Pb)_u = 1{,}751 \cdot 1{,}370 \cdot 10^{-6} = 2.40$ lb/day

Pollutant loadings calculated in Option II are lower than those in Option I and probably better represent the real situation in Atlanta, Georgia.

9.1.5 Techniques for Assessing Urban Runoff Pollution Characteristics

The material presented in the preceding sections provides states and local water quality planners with methodologies and data for predicting urban nonpoint pollutant loadings. It is not intended to serve as a basis for characterization of runoff flowing from an urbanized area. Rather, it is intended to give a first-cut assessment of nonpoint urban pollutant loading without extensive data generation.

The water pollution characteristics of urban runoff are related to both the quantity and quality of runoff. There are numerous analytical methods which have been developed for assessing the quality and quantity of runoff following a rainfall or snowmelt incidence, as a function of time. Variations of runoff characteristics with respect to time are especially important if storage, treatment, or other methods of disposal are under consideration; identification of temporal variations will enable one to identify and treat the most polluted portion of the runoff.

The presently available analytical methods to assess the water pollution characteristics of urban runoff consist of several levels of sophistication. The most accurate and definitive methods are the most difficult to utilize. Simplistic methods are available to allow the user to obtain approximate estimates.

The user is referred to the literature listed below for methods to assess the pollution characteristics of urban runoff. The analytical tools presented in these references range from simple desk calculations to sophisticated computer techniques.

Amy, G., R. Pitt, R. Singh, W. L. Bradford, and M. B. LaGraff, Water Quality Management Planning for Urban Runoff, U.S. Environmental Protection Agency, Washington, D.C. (EPA-440/9-75-004) (NTIS PB 241 689/AS) December 1974.

Brater, E. F., and J. D. Sherrill, Rainfall-Runoff Relations on Urban and Rural Areas, a study by the University of Michigan for the U.S. Environmental Protection Agency, Cincinnati, Ohio (EPA-670/2-75-046) May 1975.

DiGiano, F. A., and P. A. Mangarella (Ed.), Applications of Stormwater Management Models, Short Course Proceedings prepared by the University of Massachusetts, for the U.S. Environmental Protection Agency, Cincinnati, Ohio (EPA-670/2-75-065) June 1975.

Metcalf and Eddy, Inc., University of Florida, and Water Resources Engineers, Inc., Stormwater Management Model, U.S. Environmental Protection Agency (Report 11024 DOC 07/71), 4 Volumes, October 1971.

U.S. Corps of Engineers, Urban Runoff: Storage, Treatment and Overflow Model "STORM," U.S. Army, Davis, California, Hydrologic Engineering Center Computer Program 723-58-L2520, May 1974.

9.2 POLLUTANTS FROM MOTOR VEHICULAR TRAFFIC ON ROADWAYS

Motor vehicular traffic contributes a substantial portion of pollutant material accumulated on the surface of roadways. Significant levels of toxic heavy metals, asbestos, and slowly biodegradable petroleum products and rubber are deposited directly from motor vehicles. Contributed by traffic are also large quantities of particulate materials and nutrients. All of these constitute a significant source of water pollution.

In a recent study conducted by Biospherics, Inc.,[5/] for the U.S. Environmental Protection Agency, the deposition rates of traffic related materials were measured. The sampling activities of that study were conducted at different locations of urban roadways in Washington, D.C., with a principal objective of determining the specific contributions of motor vehicular traffic to materials deposited on roadways. During the investigation, efforts were made to isolate pollutant contributions through other mechanisms unrelated to motor vehicular traffic, such as land use, street litter, air pollutant fallout, etc.

Traffic-dependent rates of deposition of roadway surface contaminants determined by Biospherics, Inc., are given in Table 9-5. These deposition rates (Kg/axle-km, or lb/axle-mile) are highly correlated with total traffic at sampling sites and therefore considered to be traffic dependent. This is not to imply that these materials are directly emitted by motor vehicles. To the contrary, some of the traffic related materials may have origins other than with the motor vehicle itself.

Information developed by Biospherics can be used to estimate, for a specific section of a roadway, the traffic related pollutant loads using the function below:

$$Y(i)_{tr} = y(i)_{tr} \cdot LH \cdot TD \cdot AX \qquad (9\text{-}4)$$

where $Y(i)_{tr}$ = loading of pollutant i, kg/day (lb/day)

$y(i)_{tr}$ = deposition rate of pollutant i, kg/axle-km (lb/axle-km).

LH = length of highway section, km (mile)

TD = traffic density, vehicles/day

AX = average number of axles per vehicle

Table 9-5. DEPOSITION RATES OF TRAFFIC-RELATED MATERIALS[5/]

	Deposition rate		Significance of correlation (%)
	(kg/axle-km)	(lb/axle-mile)	
	(unless otherwise stated)		
Dry weight	6.67×10^{-4}	2.38×10^{-3}	< 0.1
Volume	1.77×10^{-4} (quarts/axle-km)	6.33×10^{-4} (quarts/axle-mile)	< 0.1
Volatile solids	3.39×10^{-5}	1.21×10^{-4}	< 0.1
BOD	1.52×10^{-6}	5.43×10^{-6}	< 0.1
COD	3.58×10^{-5}	1.28×10^{-4}	< 0.1
Grease	4.26×10^{-6}	1.52×10^{-5}	< 0.1
Total phosphate - P	4.03×10^{-7}	1.44×10^{-6}	< 0.1
Nitrate - N	5.29×10^{-8}	1.89×10^{-7}	< 0.1
Nitrite - N	6.33×10^{-9}	2.26×10^{-8}	< 0.1
Kjeldahl - N	1.04×10^{-7}	3.72×10^{-7}	< 2
Chloride	6.16×10^{-7}	2.20×10^{-6}	< 0.1
Petroleum	2.39×10^{-6}	8.52×10^{-6}	< 0.1
n-Paraffins	1.68×10^{-6}	5.99×10^{-6}	< 0.1
Asbestos	1.08×10^{5} (fibers/axle-km)	3.86×10^{5} (fibers/axle-mile)	< 0.1
Rubber	3.47×10^{-6}	1.24×10^{-5}	< 0.1
Lead	7.81×10^{-6}	2.79×10^{-5}	< 0.1
Chromium	5.18×10^{-8}	1.85×10^{-7}	< 1
Copper	7.95×10^{-8}	2.84×10^{-7}	< 1
Nickel	1.23×15^{-7}	4.40×10^{-7}	< 0.1
Zinc	9.8×10^{-7}	3.50×10^{-6}	< 0.1
Magnetic fraction	3.53×10^{-5}	1.26×10^{-4}	< 1

The following comments are made regarding the data (Table 9-5) developed by Biospherics, Inc.

1. These data are deposition rates of traffic related materials on roadway surfaces. They do not represent the discharge of pollutant into the surface waterways. Correlation has not yet established between the loads emitting to the streams and the dry weather accumulation on road surface.

2. These deposition rates, however, may represent, on a high side, the emission of pollutants from traffic related sources. It appears that the loads flushed to receiving water by storm events depend on the surface deposition and an attenuation factor which is influenced by the climatic characteristics of the specific location, particularly the return frequency of rainfall and runoff events sufficient to flush the surface.

3. It has been reported[1/] that a total rainfall of 0.5 in. will remove 90% of road surface particulates. The storms of following duration and intensities are considered to produce such a result:

- 0.1 in/hr for 300 min (5 hr)
- 0.33 in/hr for 90 min (1-1/2 hr)
- 0.5 in/hr for 60 min (1 hr)
- 1.0 in/hr for 30 min (1/2 hr)

It has also been reported that total rainfalls of 0.27, 0.15, 0.08 and 0.02 in. will remove 70, 50, 30, and 10% respectively, of road surface particulates. The return frequency of storms in various regions of the United States has been developed in a study conducted by the American Public Works Association for EPA.[6/]

4. A very limited amount of work on highway runoff has been reported and the loading functions or values which include effects from all pollutant sources on highways are still not available. With the absence of available data, the deposition rates established by Biospherics may be used as a first approximation, with the following understandings:

a. Pollutants originating from highways, in addition to traffic related pollutants, may also come from sources such as atmospheric fallout, litter, spill, and runoff from adjacent areas. Influences from these and other sources are not included in the given deposition rates.

b. These deposition rates were measured on urban roadways. If directly applied to highway situations, they may result in a higher prediction than that actually occurred, due to the following reasons: (a) a higher travel speed on highways than on the urban roadways, and (b) a lower frequency of stop-and-go on highways.

9.2.1 Sources of Roadway Traffic Data

Data on mileage of urban and rural roadways and annual vehicle-miles of travel are generally available at state highway departments. These data are presented in reports, such as New Mexico's "Traffic Survey, 1973," and Oregon's "Traffic Volume Tables for 1973." The states also prepare traffic flow maps showing travel on major routes.

9.2.2 Example

A 100-km section of a highway has a traffic density of 40,000 cars/day. Assuming two axles per vehicle, the following calculations are made to estimate loadings of BOD and total phosphate from Eq. (9-4).

$y(BOD)_{tr} = 1.52 \times 10^{-6}$ kg/axle-km

$Y(BOD)_{tr} = 1.52 \times 10^{-6} \times 100 \times 40{,}000 \times 2 = 12.2$ kg/day

$y(PT)_{tr} = 4.03 \times 10^{-7}$ kg/axle-km

$Y(PT)_{tr} = 4.03 \times 10^{-7} \times 100 \times 40{,}000 \times 2 = 3.2$ kg/day

9.3 STREET AND HIGHWAY DEICING SALTS

A set of loading functions for deicing salts has been developed which describes (a) average daily loading in a year, (b) average daily loading in the winter season, and (c) maximum daily loading in a 30-consecutive day period.

The 30-day minimum is negligible, since practically all of the deicing salt enters surface waters or moves to subsurface or groundwater during the winter and early spring months.

9.3.1 Loading Functions

Loading function for annual daily average - The deicing salt loading function for daily average in a year for an area under consideration is developed from (a) quantity of salt applied per year and (b) proportion of salt reaching surface water.

$$Y(DI)_{\text{average daily (annual)}} = a \cdot b \cdot DI/365 \qquad (9\text{-}5)$$

where $Y(DI)_{\text{average daily (annual)}}$ = quantity of salt loading to water course, average over 1 year, kg/day (lb/day)

a = conversion factor,
= 1,000 (MT, kg)
= 2,000 (tons, lb)

b = attenuation factor, dimensionless

DI = amount of deicer applied in the area, MT/year (tons/year)

For urban streets, the attenuation factor "b" is 1.0, with the assumption that applied salt is completely flushed into the storm sewer system and into the receiving waters.

For rural areas, the attenuation factor "b" has been found to be in the range of 0.5 to 0.9, due to losses to subsurface and groundwater. A value of 0.7 is recommended. If local values for deicing salt losses are available, however, they should be used in the loading function in preference to 0.7.

Loading function for daily average in winter season - This function is the same as Eq. (9-5) except that the denominator (365 days) is substituted by the number of days in the winter season.

Loading function for 30-day maximum - This loading function was developed by evaluating snowfall frequency in an area and salt loading per snowfall day. For the latter, the function has the form:

$$Y(DI)_{\text{snowfall day}} = a \cdot b \cdot DI/SD \qquad (9\text{-}6)$$

where $Y(DI)_{\text{snowfall day}}$ = salt loading per snowfall day, kg/day (lb/day)

SD = the number of snowdays, defined as days in which 2.5 cm (1.0 in.) or more of snow falls

The 30 day maximum load can be determined by estimating the greatest number of snowdays occurring in a 30-day period (SD_{30}). The ratio of the number of snowdays during the 30 day maximum period to the total number of snowdays in the winter season will define the percentage of the annual salt application during the 30-day period. Thus:

$$DI_{30} = DI \cdot \frac{SD_{30}}{SD} \qquad (9\text{-}7)$$

where DI_{30} = the tonnage of salt applied during the 30 day maximum period

The loading function which describes the maximum daily loading in a 30 consecutive day period, therefore, is:

$$Y(DI)_{30\text{-day maximum}} = (a \cdot b \cdot DI_{30})/30 \qquad (9\text{-}8)$$

In the northern latitudes, especially in rural areas, the largest fraction of the snowfall and applied salt remains on the ground until the spring thaw, and hence, the 30 day maximum load is shifted to the spring months. The user should rely on local experience to determine the 30 day maximum period.

9.3.2 Sources of Required Data

Number of snowdays (SD) - The number of snowdays in the winter season can be estimated with climiatic maps in The National Atlas of the United States, U.S. Department of the Interior, Geological Survey (1970), or Climatic Atlas of the United States, U.S. Department of Commerce, June 1968, or other equally suitable sources.

Amount of deicing salt applied - Data may be obtained from the following agencies:

Street departments;
Public work departments;
Highway departments; and
Tollway authorities.

Nationwide data on deicing salt application are periodically collected by and available from the Salt Institute, Alexandria, Virginia.

Appendix H of this Handbook presents available statistics relative to deicing salts application on highways. Information includes tonnage of salt (sodium and calcium chlorides) applied, application rates per snowday per unit length of single-lane roads, mileage of highways and tollways treated, and mean annual snowdays. Application figures were determined by survey in the late 1960's.

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6. American Public Works Association, "Nationwide Characterization, Impacts and Critical Evaluation of Stormwater Discharges, Nonsewered Urban Runoff and Combined Sewer Outflows, (Final Report Draft)," for the U.S. Environmental Protection Agency, Washington, D.C., August 1975.

SECTION 10.0

LIVESTOCK IN CONFINEMENT

10.1 INTRODUCTION

The loading function for livestock in confinement is applicable only to feedlots that operate without adequate runoff control facilities. The feedlots which come under either the federal NPDES permit program, or state and local regulations which require runoff control are excluded from the scope of the handbook.

State and local regulations concerning feedlot runoff control requirements vary. Sometimes these requirements may exceed those of NPDES or encompass smaller lots than the lower limits of NPDES. Thus, the loading function includes those feedlots not covered under NPDES, less those which adequately manage/control waste and pollutant runoff in response to local regulatory requirements or for other causes. Some of the added exclusions are: completely closed confinement hog and poultry lots sized below NPDES limits; and dairy lots below the NPDES limit, which control both milking operation wastes and loafing/feeding area wastes. Turkey and laying hen operations operated with the confined range management system will be included (unless runoff is controlled). The principal livestock operations covered in this handbook are thus the smaller beef, dairy, and hog operations, and poultry operations which involve confined range.

The present (1975) requirements for NPDES permits for animal confinement facilities were published in the Federal Register dated 3 May 1973. According to these requirements, the following categories of animal feedlot facilities are included under the NPDES permit program:

Slaughter steers and heifers, 1,000 head or more;
Dairy cattle, 700 head or more;
Swine over 55 lb, 2,500 or more;
Sheep, 10,000 or more;
Turkeys, 55,000 or more;
Laying hens and broilers--continuous flow watering, 100,00 or more;

Laying hens and broilers--liquid manure handling system, 30,000 or more;
Ducks, 5,000 or more; and
Combination of animals within a facility, 1,000 animal units.

The following multipliers are used to calculate the number of animal units in lots with more than one type of animal.

Slaughter steers and heifers - 1.0;
Dairy cattle - 1.4;
Swine - 0.4; and
Sheep - 0.1.

The above enumerated size limits are under review, and the handbook user should ascertain what current limits are specified before proceeding with load calculations.

Most livestock operations eventually dispose residual wastes on land--cropland, pasture, etc. The land-disposed wastes are nonpoint sources of pollution, which are covered in Section 4.0 entitled "Nutrients and Organic Matter." The loading functions presented in Section 4.0 are satisfactory for wastes disposed on land by practices which minimize or eliminate runoff incidents with land-spread manure. The data base for mismanaged land spreading is not adequate for development and use of a loading function; local judgment and estimates will be required.

On-site feedlot wastes are quite variable--by region, by season, by type of animal, and by lot management practices. Particularly variable is the on-site inventory of wastes. Beef cattle operations typically will develop a permanent net inventory of wastes over a few centimeters of the lot surface. Open poultry and hog lots will have a considerably smaller average inventory of on-site wastes on a per unit area basis. These variabilities lead naturally to wide variations in pollutant loads and concentrations carried off the lots in runoff. Thus, it has been concluded that average or typical numbers should not be presented for the convenience of the handbook user. Rather, a range of values will be presented, and the burden of determining the proper position within the range is shifted to the user.

10.2 LOADING FUNCTION FOR LIVESTOCK OPERATIONS

The loading function is based upon the premise that the size and area of individual and cumulative feedlots can be determined and located within the area under assessment, and that the following factors can be adequately established: (a) quantities of runoff, Q, from lots, as a function of appropriate units of time; (b) concentrations, C, of pollutants in the runoff; and (c) the fraction, FL_d, of runoff-contained pollutant delivered to streams. The loading function based upon these premises is:

$$Y(i)_{FL} = a \cdot Q(R) \cdot C(i)_{FL} \cdot FL_d \cdot A \qquad (10\text{-}1)$$

where $Y(i)_{FL}$ = loading rate of pollutant i from a livestock facility, kg/day (lb/day)

$Q(R)$ = direct runoff, cm/day (in/day)

$C(i)_{FL}$ = concentration of pollutant i in runoff, mg/liter

FL_d = delivery ratio

A = area of livestock facility, ha (acres)

a = a dimensional constant (0.1 metric, 0.23 English)

10.3 FEEDLOT RUNOFF EVALUATION

10.3.1 Factors in Runoff Estimation

Runoff volume is dependent upon many factors. The most important variables are: (a) amount and intensity of precipitation; (b) soil moisture condition; (c) topography including slope and surface cover; and (d) soil characteristics. Stocking rates (area per animal), which are determined in part by local precipitation patterns such as humid and arid condition, may affect the degree of compaction of the surface and thus the runoff volume.

Precipitation - Precipitation varies in duration and intensity for a given location, and average precipitation values may lead to errors in calculation of runoff volumes. Feedlot surfaces can absorb and store a definite water volume in any specific period of time, and runoff may not occur until the volume of rainfall exceeds the absorptive and storage capacity of the surface. Similarly, rainfall intensity has a significant effect on the rate of runoff and may affect the runoff volume.

Snow may accumulate on feedlots in cold climates and may not result in runoff until thaw conditions set in. Significant runoff may result from snowmelt in middle and northern latitudes of the U.S. The volume of snowmelt may be computed from records of total snowfall. The water equivalent of snow in precipitation varies significantly, but it is generally assumed that 10 in. (25 cm) of snowfall contains 1 in. (2.5 cm) of water.1/

Soil moisture - The amount of runoff is affected by the degree of saturation of soil with water. A dry soil-manure mixture has greater capacity to absorb precipitation and to retain moisture than a wet mixture. Antecedent precipitation is thus an important factor in determining the soil moisture. When one rain follows closely after another of equal intensity and duration, a greater volume of runoff may result from the second rain.

Topography - The slope and surface cover, i.e., whether concrete lot or dirt lot, may affect the runoff volume. For feedlot situations, the effect of slope on runoff volume was not shown to be significant. The effect of paving the lot surface, however, was reported to be significant. Manure handling practices, including frequency of cleaning the surface, may have an effect on the amount of runoff. Even on unsurfaced feedlots, the surface soil-manure mixture is subject to compaction and tends to provide a sufficient and effective barrier to seepage. This is especially true in a continuously operating feedlot.

Soil characteristics - A coarse, sandy soil has a greater infiltration capacity than a clay soil. The infiltration capacity for bare soils is in the range of 0.5 to 1.0 in/hr (1.25 to 2.5 cm/hr) for sandy soils, 0.1 to 0.50 in/hr (0.25 to 1.25 cm/hr) for intermediate soils, and 0.01 to 0.10 in/hr (0.025 to 0.25 cm/hr) for clay and clay loam type soils. These rates are for bare soils which are not excessively trampled or excessively compacted. The movement of animals within the lot will often create a soil-manure mixture at the surface, which will reduce the natural infiltration capacity of the soil and increase the runoff volume.

10.3.2 Precipitation Data Analysis

The single most important characteristic of precipitation is its variability. Estimation of runoff will be greatly influenced by the quality of precipitation data. In general, the longer the record, the better is the estimate of probable precipitation for a given location. A 1-year precipitation record is not a good indicator of the probable occurrence of precipitation in the future, but there is no simple way to determine *a priori* what length of records will give a reliable estimate of average precipitation in a given location.

Depending upon the time and resources available, the local planner should determine the length of records that must be included in the analysis. A wide variety of precipitation data is available. Local climatological data are issued on a monthly basis by the U.S. Department of Commerce--National Oceanic and Atmospheric Administration. Table 10-1 shows the locations by state for which weather records are issued. There are three categories of publications which will help to determine the amount of daily precipitation for a given location:

Table 10-1. STATIONS FOR WHICH LOCAL CLIMATOLOGICAL DATA ARE ISSUED, AS OF 1 JANUARY 1974

	ALABAMA
abc	Birmingham
abc	Huntsville
abc	Mobile
abc	Montgomery
	ALASKA
abc	Anchorage
abc	Annette
abc	Barrow
abc	Barter Island
abc	Bethel
abc	Bettles
abc	Big Delta
abc	Cold Bay
abc	Fairbanks
abc	Gulkana
abc	Homer
abc	Juneau
abc	King Salmon
abc	Kodiak
abc	Kotzebue
abc	McGrath
abc	Nome
abc	St. Paul Island
abc	Summit
abc	Talkeetna
abc	Unalakleet
abc	Yakutat
	ARIZONA
abc	Flagstaff
abc	Phoenix
abc	Tucson
abc	Winslow
abc	Yuma
	ARKANSAS
abc	Fort Smith
abc	Little Rock
	CALIFORNIA
abc	Bakersfield
abc	Bishop
ac	Blue Canyon
ac	Eureka
abc	Fresno
abc	Long Beach
abc	Los Angeles Airport
ac	Los Angeles Civic Center
abc	Mt. Shasta
abc	Oakland
abc	Red Bluff
abc	Sacramento
abc	Sandberg
abc	San Diego
	San Francisco
abc	Airport
ac	City
abc	Santa Maria
abc	Stockton
	COLORADO
abc	Alamosa
abc	Colorado Springs
abc	Denver
abc	Grand Junction
abc	Pueblo
	CONNECTICUT
abc	Bridgeport
abc	Hartford
	DELAWARE
abc	Wilmington
	DISTRICT OF COLUMBIA
abc	Washington-National AP
abc	Washington-Dulles Int'l AP
	FLORIDA
ac	Apalachicola
abc	Daytona Beach
abc	Fort Myers
abc	Jacksonville
abc	Key West
ac	Lakeland
abc	Miami
abc	Orlando
abc	Pensacola
abc	Tallahassee
abc	Tampa
abc	West Palm Beach
	GEORGIA
abc	Athens
abc	Atlanta
abc	Augusta
abc	Columbus
abc	Macon
ac	Rome
abc	Savannah
	HAWAII
abc	Hilo
abc	Honolulu
abc	Kahului
abc	Lihue
	IDAHO
abc	Boise
abc	Lewiston
abc	Pocatello
	ILLINOIS
ac	Cairo
	Chicago
abc	Midway Airport
abc	O'Hare Airport
abc	Moline
abc	Peoria
abc	Rockford
abc	Springfield
	INDIANA
abc	Evansville
abc	Fort Wayne
abc	Indianapolis
abc	South Bend
	IOWA
abc	Burlington
abc	Des Moines
abc	Dubuque
abc	Sioux City
abc	Waterloo
	KANSAS
abc	Concordia
abc	Dodge City
abc	Goodland
abc	Topeka
abc	Wichita
	KENTUCKY
abc	Lexington
abc	Louisville
	LOUISIANA
abc	Alexandria
abc	Baton Rouge
abc	Lake Charles
abc	New Orleans
abc	Shreveport
	MAINE
abc	Caribou
abc	Portland
	MARYLAND
abc	Baltimore
	MASSACHUSETTS
abc	Boston
ac	Blue Hill Obs.
abc	Worcester
	MICHIGAN
abc	Alpena
	Detroit
abc	City Airport
abc	Detroit Metro AP
abc	Flint
abc	Grand Rapids
abc	Houghton Lake
abc	Lansing
ac	Marquette
abc	Muskegon
abc	Sault Ste. Marie
	MINNESOTA
abc	Duluth
abc	International Falls
abc	Minneapolis-St. Paul
abc	Rochester
abc	St. Cloud
	MISSISSIPPI
abc	Jackson
abc	Meridian
	MISSOURI
abc	Columbia
abc	Kansas City
abc	St. Joseph
abc	St. Louis
abc	Springfield
	MONTANA
abc	Billings
abc	Glasgow
abc	Great Falls
abc	Havre
abc	Helena
abc	Kalispell
abc	Miles City
abc	Missoula
	NEBRASKA
abc	Grand Island
abc	Lincoln
abc	Norfolk
abc	North Platte
abc	Omaha
abc	Scottsbluff
ac	Valentine
	NEVADA
abc	Elko
abc	Ely
abc	Las Vegas
abc	Reno
abc	Winnemucca
	NEW HAMPSHIRE
abc	Concord
ac	Mt. Washington
	NEW JERSEY
	Atlantic City
abc	Airport
a	State Marina
abc	Newark
ac	Trenton
	NEW MEXICO
abc	Albuquerque
ac	Clayton
abc	Roswell
	NEW YORK
abc	Albany
abc	Binghamton
	NEW YORK (Contd.)
abc	Buffalo
	New York
abc	Central Park
abc	J.F. Kennedy Int'l AP
abc	LaGuardia Field
abc	Rochester
abc	Syracuse
	NORTH CAROLINA
abc	Asheville
abc	Cape Hatteras
abc	Charlotte
abc	Greensboro
abc	Raleigh
abc	Wilmington
	NORTH DAKOTA
abc	Bismarck
abc	Fargo
abc	Williston
	OHIO
abc	Akron-Canton
	Cincinnati
ac	Abbe Obs.
abc	Airport
abc	Cleveland
abc	Columbus
abc	Dayton
abc	Mansfield
abc	Toledo
abc	Youngstown
	OKLAHOMA
abc	Oklahoma City
abc	Tulsa
	OREGON
abc	Astoria
abc	Burns
abc	Eugene
abc	Meacham
abc	Medford
abc	Pendleton
abc	Portland
abc	Salem
abc	Sexton Summit
	PACIFIC ISLANDS
abc	Guam
abc	Johnston
abc	Koror
abc	Kwajalein
abc	Majuro
abc	Pago Pago
abc	Ponape
abc	Truk (Moen)
abc	Wake
abc	Yap
	PENNSYLVANIA
abc	Allentown
abc	Erie
abc	Harrisburg
abc	Philadelphia
	Pittsburgh
abc	Airport
ac	City
abc	Scranton
abc	Williamsport
	RHODE ISLAND
ac	Block Island
abc	Providence
	SOUTH CAROLINA
	Charleston
abc	Airport
a	City
abc	Columbia
abc	Greenville-Spartanburg
	SOUTH DAKOTA
abc	Aberdeen
abc	Huron
abc	Rapid City
abc	Sioux Falls
	TENNESSEE
abc	Bristol
abc	Chattanooga
abc	Knoxville
abc	Memphis
abc	Nashville
ac	Oak Ridge
	TEXAS
abc	Abilene
abc	Amarillo
abc	Austin
abc	Brownsville
abc	Corpus Christi
abc	Dallas
abc	Del Rio
abc	El Paso
abc	Fort Worth
ac	Galveston
abc	Houston
abc	Lubbock
abc	Midland
abc	Port Arthur
abc	San Angelo
abc	San Antonio
abc	Victoria
abc	Waco
abc	Wichita Falls
	UTAH
ac	Milford
abc	Salt Lake City
abc	Wendover
	VERMONT
abc	Burlington
	VIRGINIA
abc	Lynchburg
abc	Norfolk
abc	Richmond
abc	Roanoke
ab	Wallops Island
	WASHINGTON
abc	Olympia
abc	Quillayute Airport
abc	Seattle-Tacoma AP
ac	Seattle Urban Site
abc	Spokane
abc	Stampede Pass
ac	Walla Walla
abc	Yakima
	WEST INDIES
abc	San Juan, P. R.
	WEST VIRGINIA
abc	Beckley
abc	Charleston
abc	Elkins
abc	Huntington
ac	Parkersburg
	WISCONSIN
abc	Green Bay
abc	La Crosse
abc	Madison
abc	Milwaukee
	WYOMING
abc	Casper
abc	Cheyenne
abc	Lander
abc	Sheridan

a. Monthly summary issued.   b. Monthly summary includes available 3-hourly observations. Published if 5 or more available per day.   c. Annual Summary issued.

1. Hourly precipitation data at various stations in each state are reported by month. Daily summaries are also included. These data are extensive, and can be used to determine precipitation amounts for a given location quite accurately. Table 10-2 shows typical results for Missouri in January 1974.

2. Local climatological data for a given station are summarized by month. Data are given on a daily basis, and at 3-hr intervals. An example of the type and extent of data in this category is shown in Table 10-3 during the month of January for the weather station located at International Airport in Kansas City, Missouri.

3. Climatological data for each state are reported monthly. These data include both the official observatory data and data from other private and public climatological records. These data are presented on a daily basis. Typical precipitation data for parts of Missouri during January 1974 are presented in Table 10-4.

10.3.3 Estimation of Runoff from Feedlots

The quantity of pollutants discharged from a feedlot depends largely upon the runoff volume and the pollutant concentration in the runoff. Limited data on cattle feedlot runoff characteristics in terms of various pollutant concentrations are presented later in Tables 10-10 and 10-11.

The overall method consists of estimation of probable storm events for the period of interest, by analysis of historic data, calculation of runoff from individual storm events, and summation of runoff from all storm events. The period of interest may be a year, or some fraction of a year--usually 30 days.

Methods for estimating runoff volumes from feedlots may be divided into two categories:

1. Soil Conservation Service (SCS) Method; and

2. Empirical Regression Method.

Both the methods predict runoff volume from a given precipitation event. The SCS method utilizes the concept of soil cover and hydrologic (infiltration) capacity of soil in calculating runoff. The regression method, as the name implies, is based on the linear regression of observed rainfall-runoff relationships for any given location. Because of the variability of the observed runoff patterns, and also because the regression coefficients may not be established adequately for a given location, the regression method is considered to be less reliable in predicting runoff volumes.

Table 10-2. HOURLY PRECIPITATION

HOURLY AMOUNTS

MISSOURI
JULY 1974

STATION	DATE	A.M. Hour Ending												P.M. Hour Ending												TOTAL
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
		MONTHLY MAXIMUM AMOUNTS																								
		HOURS			1			2			3			6			12			24			ACCUMULATION			
		MINUTES			15			30			45			60			120			180						
		(Apply heading as appropriate)																								
HORNERSVILLE		AMOUNT DATE/TIME OF ENDING			.43 22/10:00P			.64 22/11:00P			.68 22/12:00P			.99 23/2:00A			1.00 23/3:00A			1.00 23/3:00A						
JEFFERSON CITY L U	4	.1	.2	.2	.1																					.6
	15			.1																						.1
	25																	.1								.1
		AMOUNT DATE/TIME OF ENDING			.2 4/3:00A+			.4 4/3:00A			.5 4/4:00A+			.6 4/4:00A			.6 4/4:00A			.6 4/4:00A						
		AMOUNT DATE/TIME OF ENDING			.1 25/4:30P+			.2 4/2:15A			.2 4/3:15A+			.3 4/2:45A			.4 4/3:15A+			.6 4/3:15A						
JEFFERSON BARRACKS 2SW	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		AMOUNT DATE/TIME OF ENDING			-			-			-			-			-			-						
		AMOUNT DATE/TIME OF ENDING			-			-			-			-			-			-						
JEWETT 7 E	10													.12				.01								.13
	14																.45									.45
		AMOUNT DATE/TIME OF ENDING			.45 14/4:00P			.45 14/4:00P			.45 14/4:00P			.45 14/4:00P			.45 14/4:00P			.45 14/4:00P						
KANSAS CITY WSMO AP	3	*																				.34	.32	.13	.33	1.12
	25										.01															.01
		AMOUNT DATE/TIME OF ENDING			.34 3/9:00P			.66 3/10:00P			.79 3/11:00P			1.12 3/12:00P			1.12 3/12:00P			1.12 3/12:00P						
KANSAS CITY SWOPE PARK	3																						.3	.8	.1	1.2
	4	.1																								.1
		AMOUNT DATE/TIME OF ENDING			.8 3/11:00P			1.1 3/11:00P			1.2 3/12:00P			1.3 4/1:00A			1.3 4/1:00A			1.3 4/1:00A						
		AMOUNT DATE/TIME OF ENDING			.4 3/10:45P			.6 3/11:00P			.7 3/11:15P+			.8 3/11:15P+			1.2 3/11:15P			1.2 3/11:15P						
KEARNEY																					.3	.2		.1		.6
		AMOUNT DATE/TIME OF ENDING			.3 3/8:00P			.5 3/9:00P			.5 3/9:00P			.6 3/11:00P			.6 3/11:00P			.6 3/11:00P						
		AMOUNT DATE/TIME OF ENDING			.3 3/8:00P			.4 3/8:15P			.4 3/8:15P			.4 3/8:15P			.5 3/9:00P			.6 3/10:15P						
KIRKSVILLE RADIO KIRX	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		AMOUNT DATE/TIME OF ENDING			-			-			-			-			-			-						
		AMOUNT DATE/TIME OF ENDING			-			-			-			-			-			-						
LAKESIDE	4	.1	.2	.2																						.5
	15			.1																						.1
	22							.1																		.1
	25															.3										.3

Table 10-3

Kansas City, Missouri
Nat Weather Service Met Obsy
International Airport
January 1974

LOCAL CLIMATOLOGICAL DATA

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
ENVIRONMENTAL DATA SERVICE

Latitude 39° 17' N Longitude 94° 43' W Elevation (ground) 1014 ft Standard time used CENTRAL WBAN #03947

Weather types on dates of occurrence: 1 Fog; 2 Heavy fog X; 3 Thunderstorm; 4 Ice pellets; 5 Hail; 6 Glaze; 7 Duststorm; 8 Smoke, Haze; 9 Blowing snow

Date	Temperature °F: Maximum	Minimum	Average	Departure from normal	Average dew point	Degree days Base 65: Heating	Cooling	Weather types on dates of occurrence	Snow, ice pellets or ice on ground at 06AM In	Precipitation: Water equivalent In	Snow, ice pellets In	Avg station pressure In. Elev 1025 feet m.s.l.	Wind: Resultant direction	Resultant speed m.p.h.	Average speed m.p.h.	Fastest mile: Speed m.p.h.	Direction	Sunshine: Hours and tenths	Percent of possible	Sky cover Tenths: Sunrise to sunset	Midnight to midnight	Date
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0	-13	-7*	-35	-16	72	0	8	4	.04	.5	29.40	35	2.5	4.6	9	E	7.7	82	4	5	1
2	10	0	5	-23	- 5	60	0	8	4	.07	.7	29.32	07	5.0	6.5	13	E	6.7	71	10	8	2
3	15	3	9	-19	0	56	0		4	0	0	29.36	33	7.5	7.6	10	NW	8.0	84	6	5	3
4	17	-1	8	-20	- 2	57	0	1 8	4	0	0	29.20	07	2.2	4.0	10	NE	8.0	84	1	2	4
5	18	1	10	-18	3	55	0		4	0	0	29.08	06	5.1	5.3	12	N	7.1	75	10	9	5
6	17	1	9	-19	6	56	0	1	3	T	T	28.92	35	4.6	8.2	13	NW	6.7	70	5	6	6
7	17	-3	7	-21	- 4	58	0		3	0	0	29.00	14	2.8	6.6	10	E	7.8	82	8	6	7
8	13	2	8	-19	2	57	0	4 6 8	3	.12	.9	28.92	02	8.4	12.4	20	NW	1.2	12	10	7	8
9	7	-1	3	-24	- 6	62	0	8	4	.20	2.3	29.10	02	9.8	11.1	15	NE	5.4	56	9	7	9
10	12	3	8	-19	4	57	0	1 8	7	.03	.4	28.98	02	10.9	11.7	13	N	5.5	57	10	8	10
11	6	-9	-2	-29	-11	67	0	1	7	0	0	29.23	32	7.6	7.8	11	NW	10.0	100	1	1	11
12	8	-13*	-3	-30	-13	68	0	1	7	0	0	29.40	12	3.2	7.3	13	E	7.5	77	9	7	12
13	27	7	17	-10	12	48	0	8	7	0	0	29.16	17	6.9	8.8	15	S	6.1	63	10	10	13
14	39	24	32	5	22	33	0	1 8	7	0	0	28.99	21	9.4	10.1	16	S	9.1	94	1	1	14
15	42	29	36	9	25	29	0	8	6	0	0	28.93	21	10.4	10.5	17	S	7.9	80	10	8	15
16	43	33	38	11	30	27	0	1	0	0	0	28.83	21	11.7	12.1	19	SW	8.3	85	6	4	16
17	43	30	37	10	35	28	0	2 8	3	0	0	28.82	19	6.3	6.9	11	S	5.6	57	10	9	17
18	40	33	37	10	32	28	0	2	T	T	0	28.87	36	7.8	8.9	18	N	0.6	7	10	10	18
19	34	31	33	6	28	32	0	2 6	T	.02	0	28.87	04	5.5	6.5	15	N	0.0	0	10	10	19
20	39	33	36	8	30	29	0	2 8	T	.12	0	28.66	26	4.0	4.8	11	W	3.8	39	10	8	20
21	37	33	35	7	29	30	0	1	T	T	0	28.87	03	3.9	6.6	17	NE	1.1	11	10	10	21
22	35	30	33	5	26	32	0	1 8	T	.12	0	28.92	34	9.7	10.5	17	NW	0.7	7	10	10	22
23	41	25	33	3	23	32	0	1	T	0	0	29.09	24	5.0	6.2	10	SW	9.0	91	4	3	23
24	48	28	38	10	25	27	0		0	0	0	29.14	21	4.8	5.2	7	SW	9.8	92	0	0	24
25	53	30	42	14	27	23	0		0	0	0	29.02	19	8.3	8.6	21	SW	9.7	97	0	0	25
26	44	34	39	11	31	26	0	1	0	.30	0	28.60	19	6.8	7.6	19	S	0.3	3	10	8	26
27	36	29	33	4	25	32	0	4 6	0	.02	T	28.87	33	5.3	6.8	17	NW	5.7	57	10	9	27
28	47	28	38	9	27	27	0	1 4 6 8	T	.01	T	28.80	21	2.8	5.0	16	SW	9.1	90	1	4	28
29	56	35	46	17	32	19	0		0	0	0	28.80	21	10.3	10.4	16	S	9.5	92	1	2	29
30	60*	39	50*	21	34	15	0		0	0	0	28.67	20	14.5	14.5	23	SW	9.3	91	3	1	30
31	44	26	35	5	20	30	0		0	0	0	28.94	01	7.6	11.8	22	NW	8.8	87	4	4	31

Sum	Sum				Total	Total		Total	Total	For the month						Total	% for month	Sum	Sum
948	527				1272	0	Number of days	1.05	4.8	28.99	26	.8	8.2	23	SW	196.0		203	182
Avg	Avg	Avg	Dep	Avg	Dep	Dep	Precipitation	Dep						Date	30	Possible		Avg	Avg
30.6	17.0	23.8	-4.0	15	119	0	≥ .01 inch 11	-0.20								303.2	65	6.5	5.9

				Season to date		Snow, ice pellets
Number of days				Total	Total	≥ 1.0 inch 1
Maximum Temp		Minimum Temp		3153	0	Thunderstorms 0
≥ 90° ‡	≤ 32°	≤ 32°	≤ 0°	Dep	Dep	Heavy fog X 4
0	13	24	7	67	0	Clear 8 Partly cloudy 6 Cloudy 17

Greatest in 24 hours and dates: Precipitation		Snow, ice pellets		Greatest depth on ground of snow, ice pellets or ice and date	
.30	26	2.6	9-10	7	14+

HOURLY PRECIPITATION (Water equivalent in inches)

Date	A.M. Hour ending at 1	2	3	4	5	6	7	8	9	10	11	12	P.M. Hour ending at 1	2	3	4	5	6	7	8	9	10	11	12	Date
1																						.01	.02	.01	1
2	.02	.02	.02	.01																					2
3																									3
4																									4
5																									5
6									T	T	T														6
7																									7
8										T	.02	.03	.02	.02	.02	T	T	.01	T	T	T	T			8
9													T	T	T	.04	.03	.05	.02	.01	.02	.01	.01	.01	9
10	T	T	.01	.01	T	T	.01	T	T	T	T	T		T	T	T	T	T	T	T	T				10
11																									11
12																									12
13																									13
14																									14
15																									15
16																									16
17																									17
18																								T	18
19						T	T	T	T						.02	T		T	T	T	T	T	T	T	19
20		T	T			.01	.05	.04	.02	T															20
21																							T	T	21
22	T	T	.06	T	.04	.01	.01	T			T	T													22
23																									23
24																									24
25																									25
26								T	.04	.04	.04	.06	.06	.03	.03	T	T								26
27																		.01	.01	T	T	T	T	T	27
28	T	T	.01	T	T																				28
29																									29
30																									30
31																									31

* Extreme temperatures for the month. May be the last of more than one occurrence.
– Below zero temperature or negative departure from normal.
‡ ≥ 70° at Alaskan stations.
+ Also on an earlier date, or dates.
X Heavy fog restricts visibility to ¼ mile or less.
T In the Hourly Precipitation table and in columns 9, 10, and 11 indicates an amount too small to measure.

The season for degree days begins with July for heating and with January for cooling.

Data in columns 6, 12, 13, 14, and 15 are based on 8 observations per day at 3-hour intervals.

Wind directions are those from which the wind blows. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. Figures for directions are tens of degrees from true North, i.e., 09 = East, 18 = South, 27 = West, 36 = North and 00 = Calm. When directions are in tens of degrees in Col. 17, entries in Col. 16 are fastest observed 1-minute speeds. If the / appears in Col. 17, speeds are gusts.

Any errors detected will be corrected and changes in summary data will be annotated in the annual summary.

Subscription Price: Local Climatological Data $ 2.00 per year including annual issue if published, foreign mailing 75¢ extra. Single copy: 20¢ for monthly issue; 15¢ for annual summary. Make checks payable to Department of Commerce, NOAA. Send payments and orders to National Climatic Center, Federal Building, Asheville, North Carolina 28801.

I certify that this is an official publication of the National Oceanic and Atmospheric Administration, and is compiled from records on file at the National Climatic Center, Asheville, North Carolina 28801.

William H. Haggard
Director, National Climatic Center

SUMMARY BY HOURS

Hour Local time	AVERAGES: Sky cover tenths	Station pressure In.	Temperature: Air °F	Wet bulb °F	Dew Pt. °F	Relative humidity %	Wind speed m.p.h.	Resultant wind: Direction	Speed m.p.h.
00	4	29.00	22	20	14	72	7.4	30	1.2
03	5	28.99	21	19	14	73	7.9	30	1.0
06	5	28.99	20	18	13	74	7.8	30	1.1
09	6	29.02	21	19	14	74	7.6	21	.6
12	7	29.02	27	24	16	66	8.3	24	1.7
15	6	28.97	29	26	17	62	9.3	27	2.4
18	6	28.97	27	24	17	66	8.8	07	.3
21	6	28.98	25	22	16	70	8.6	17	1.3

USCOMM — NOAA — ASHEVILLE 475

NOTICE: CLIMATOLOGICAL NORMALS BASED ON THE PERIOD 1941-1970 ARE EFFECTIVE AS FOLLOWS
HEATING DEGREE DAYS - JULY 1, 1973
COOLING DEGREE DAYS, TEMPERATURE, AND PRECIPITATION - JANUARY 1, 1974

Table 10-4. DAILY PRECIPITATION

MISSOURI
JANUARY 1974

Station	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
• • • NORTHWEST PRAIRIE 01																																
AMITY	1.36		.10				T	.02		.29	.31	T									.22		.15				.13	.40				
BETHANY	1.90	T	.12				.04	.02		.29	.21	.06							.02	T	.30	.05	.20	.07				.92				
BROOKFIELD	2.08	.03	.05					T		.32	.29	.08									.15	.07	.07	.02				.93	.07			
BRUNSWICK	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BURLINGTON JUNCTION	1.59		.15				.06	.06		.25	.17	.09									.40	.20	.05	T				.12				
CARROLLTON	1.65		.02				T		.21	.09	.37			T				.01	.02	.15	.08	T	.12				.60	T	.16			
CHILLICOTHE	1.49		.20							T	.28	.05										.21	.03					.72				
CHILLICOTHE RADIO KCHI	1.04		.06				.01		.22	.10	.28	T		T						.19	.04	.02	.13	T			.49	.06	.02			
COLOMA	1.82						T			.12	.22								T	T	.30	.02	.18					.70	.08			
CONCEPTION	1.59	T	.10				.10			.48	.15	.03							T	T	.42	T	.05	T				.80				
CONCORDIA	2.26	.02	T							.18	.47	.02			T					.06	.20	T	.42					.63	.20			
EDGERTON	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.43				
FAIRFAX	-		.19			-	.04			.27	-	.22								-	-	-	-		T			.05				
FAYETTE	1.69					T			.01	.23	.04								T	.17	.18		.23				.48		.35			
FOUNTAIN GROVE WL	1.83		.04				T		.18	.06	.38								T	.27	.11		.05				.49	.25	T			
GALLATIN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GRANT CITY	1.57		.12				.07	T		.36	.25	.03									.35	.05						.34				
HAMILTON 2 W	1.38		.05							.20	.21	T									.18	T	.14					.35				
INDEPENDENCE TRUMAN LB	1.62	T	.13							.16	.37	.02			T					T	.22	.02	.19	T			T	.31	.02			
KANSAS CITY INT WSO AP R	1.05	.04	.07				T		.12	.20	.09								T	.02	.12	T	.12				.90	.02	.03			
KING CITY	-						.08		.39D	.40	.08							T	T		.25		.22				-	-	-			
LEES SUMMIT REED WLR	1.75								.19	.12	.30									.10		.02	.28				.35		.20			
LEXINGTON	1.84	.02	.03					T		.19	.42	.02								.01	.17	.04	.21	T				.56	.17			
LUCERNE	-					T	T			T	.20D	.70									-		-					.43				
MARSHALL	D 1.90								.01D	.15									.04		.35	.15	.28				.83	.10	.27			
MARYVILLE 2 E	1.31		.08				.05	T		.30	.04	.02							.03	T	.44	.06	.08					.19				
MERCER 6 NW	1.80			T			.10			[illegible]	.10	.10								T	.50		.2[illegible]				.30					
MILAN	1.81	T	.05				T			.18	.15	.08			T					T	.30	T	.25				T	.80	T			
NEW FRANKLIN 1 W	3.12								.13	.05	.47								.07	.22	.41	T	.57				.59	.12	.49			
ODESSA	3.79									.22	.01				1.59						.26		.35					.56	.26			
OREGON	1.26		.10				.08			.30	.05	.33							.02		.35	.05	.07					.08				
PLATTSBURG WATERWORKS	1.72		.11							.31	.34	.07									.13	.12	.16	.03				.45				
POLO	1.54	.04	.03				T			.20	.21	T								T	.18	.10	.19	T				.56	.03			
PRINCETON 4 SW	1.46		.20				.02		.14	T	.12									T	.24		.20				.56					
ST. JOSEPH 4 WNW	1.24		.08				T		.23	.04	.20	T		T						T	.16	.04	.16				.33	T	T			
SALISBURY	2.34		.02						.14	.11	.40	.05						T	.08	.43	.12		.19				.82	T	.22			
SPICKARD 7 W	1.53		.08				.03		.20	T	.13	T		T				T	T	.03	.31	T	.20				.53					
SUMNER 3 WSW	1.70	•	•	•	•	•	•	•	•	•	•	•	•	•	.92						.13		T					.65	T			
SWEET SPRINGS	2.97			T			T		.20	.11	.61	T		T				T	.04	.48	.08	T	.42				.71		.34			
TARKIO	1.31		.20				.07		.21	T	.22			T					T	T	.52		.04				.05					
TRENTON	1.58		.05					T		.18	.15	.08						T	T	.04	.21		.12	.12				.63				
UNIONVILLE	1.97	T	.06				T	.06		.21	.11	.07			T				T	T	.33	.02	.14	.19				.78				
WAVERLY	-										.05				1.40						-	-	-					1.05	.20			
• • • NORTHEAST PRAIRIE 02																																
AUXVASSE	4.03								T	.49									.83		.32		.74				1.30		.30			
BOWLING GREEN 2 NE	-								•	•	.08										.70	1.30						-	-	-		
CANTON LOCK AND DAM 20//	2.97	.02	.03					.02		.30	.40	.09								.01	.73	.02	.06	.16				.98	.15	T		
CENTRALIA	3.10									.16	.56								.32	.30	.26							1.25	.23			
COLUMBIA WSO AP R	3.58						T		.15	.40	.07	T	T					T	.45	.12	.14		.65				1.24	T	.36			
EDINA	2.12	T	.04					.02		.30	.26	.05							T	.02	.18	T	T	.28				.97	T			
ELSBERRY 1 S	-									-	-	-							.19	.13	1.36	.58	.18	.37				.88	.18	.17		
FREEDOM	-					.24			.08	-	-								.02	.07	.03		.70				.85	.04	.33			
FULTON	2.99	T						T		.13	.36	.01							.12	.18	.12	.14	.14	.33				1.08	.15	.23		
GERALD	3.76							.10	.30	.05	.20								.20	.30	1.00	.35					.75		.51			
GREGORY LANDING	2.88	T	T					.02		.23	.26	.11								T	.73	.11	.12	.08				1.18	.04	T		
HANNIBAL WATERWORKS	2.96		T					T		.31	.27	.30	T						T	.16	.10	.34	.04	.16				1.12		.18		
HERMANN	3.68	.05						T		.13	.55	.03	T							T	.35	.74	.02	.60				.78	.05	.42		
KAHOKA	3.13		T				T		.20	.11	.14	T									.97		.74				.84	.13	T			
KIRKSVILLE RADIO KIRX	7.42		.02				.01		[illegible]	.02	.17								.01	.15	.30		.37				.92	.20	.05			
LA BELLE	1.93		T					T		.13	.25	.04									.30	.07	.11	.10				.89	.04			
LOUISIANA STARKS NUR	2.29										.37												.50				1.21		.17			
LOUISIANA	4.07	T						T		.23	.31	.05							T	.64	.40	.48	.17	.28				1.34		.17		
MACON	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MADISON	3.74									.23	.41	.02								.68		.18						1.01	.41			
MARTINSBURG	4.27								.02	.03	.40								1.10	.03	.42	.01	.70				1.23	.03	.30			
MEMPHIS	2.70	.02	.05					.01		.16	.23	.09									.46	.03	.36	.15				1.08		.04		
MEXICO	2.87									.12	.44	.03							.42	.14	.25	.08	.25	.10			.05	.87	.10			
MOBERLY RADIO KWIX	3.01		T						.21	.06	.45								.15	.30	.35	.01	.25			T	.71	.13	.39		T	
MONROE CITY	-									-	.30	-								.25	-	-	.41					.93	-	-		
NEW FLORENCE	3.52						T	T	.11	T	.50	T							.27	.03	.93	T	.38				.90	.12	.28			
OWENSVILLE	4.30									.05	T	.85	T						T	1.45	.45		T	.20			T	1.00	.13	.1[illegible]		
PACIFIC	3.89	T					T			.14	.62	.02	T							.18	.82	.83	.24	.24				.42	.23	.15		
PALMYRA	2.80		T				T			.18	.29	.08								.47	.24	.13	.11	.05				1.02	.23	T		
PARIS	3.47					.04			.21	.51									.45	.85	.05	.15				.06	.82	.33				
SAINT CHARLES	4.71	.04								.23	.60	T							T	.41	.49	1.89	.02	.33				.05	.03	.40		
ST LOUIS GATEWAY ARCH	2.46						T			T		.70					.06		.01	.07	.43	.34	T				.01	.33	.23	.24	T	
SAINT LOUIS WSO AP R	3.51						T		.19	.42	.08	.01		T					.29	.27	.78		.45				.83		.30			
SAVERTON L AND D 22 //	2.73	T						T		.22	.30	.01								.09	.22	.29	.15	T				1.39	T	.09		
SHELBINA	2.24						T			.15	.23	.04							T	.03	.44	.07	.14	.09			T	.76	.22	.05		
SHELBYVILLE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
STEFFENVILLE	2.33	.03	.03				T	.02		.21	.22	.07							T	T	.53	.07	.07	.13				.85	.07	.03		
SULLIVAN 3 SE	2.84										.72									.20	.94							.73	.23			
TROY	4.90	.02						T		.08	.51	T								.30	1.00	.90	.20	.55			.08	.63	.25	.18		
UNION	4.42	.08								.13	.81	.01								.11	.70	1.05	.01	.44				.52	.09	.47		
VALLEY PARK	3.60	.05								.12	.58	T								.38	.76	.27	T	.38				.46	.33	.27		
VANDALIA	2.01									.19	.43	.03							.12	.08	.12	.33	.42	.07					.26			
WARRENTON 1 N	-								-	-	-									.10	.80	.22					.66	.18				
WEBSTER GROVES	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WELDON SPRNG WLDLFE AR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
• • • WEST CENTRAL PLAINS 03																																
APPLETON CITY	2.96								.20	.28	.85	T							.02	.38	.03		.58				.60		.38			
BOONVILLE WATERWORKS	3.21	T								.07	.45	.07							.17	T	.60	T	.43	.10				.84	.43	.03		
BUTLER	3.07	.01	T							.18	1.08	T							.05	.05	.25	T	.65	T				.52	.28	T		
CALIFORNIA	-								-	-	-									.20	.08		.56				.16		.25			
CAMDENTON	3.20						T		.10	.19	.46									.39	.18	T	.39				.97	.02	.36			
CAPLINGER MILLS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CLIFTON CITY	2.96									T	.69				.08						.32	T		.06				.07	.67	.05		
CLIMAX SPRINGS	3.15								.05	.25	.36								.04	.21	.15		.31				1.07		.71			
CLINTON 3 NW	-									.22	.32	T									-		-					.74	-			
COLE CAMP 9 SE	2.79	.02								.12	.39	T							.08	.02	.23	T	.24	.09			.12	.76	.33	.03		
ELDON	3.57								.02	.16	.43	T							T	.43	.18		.53				1.12		.68			
ELDORADO SPRINGS	2.21				T				.06	.25										.33	.06		.20				.35	T				
HARRISONVILLE	2.23										1.00										.20		.43					.42	.20			
JEFFERSON CITY L U	-								.10	-	.32	T							.05	-	-		.80				1.05	.08	.31			
LAKESIDE	2.98									.18	.30					T					.27	.05	.04	.36				1.04	.40	T		
NEVADA SEWAGE PLANT	2.35	.02								.18	.74	T									.42		.17	.07				.47	.53			
OSCEOLA	3.34			T					.18	.50	.30								T	.44	.30		.21	T			.71	.02	.70			

However, because of the simple format, the regression method may be easier to use on a routine basis, especially when adequate experimental data exist.

10.3.3.1 Soil conservation service (SCS) method -

The Soil Conservation Service of the U.S. Department of Agriculture has developed a method of estimating direct runoff from small agricultural plots due to single storm events.[2] The rainfall-runoff relationship given by SCS is:

$$Q = \frac{(Pr - 0.2S)^2}{(Pr + 0.8S)} \qquad (10\text{-}2)$$

where Q = direct runoff, cm (in.)

Pr = storm rainfall, cm (in.)

S = potential infiltration, cm (in.)

S is defined in terms of runoff curve number (CN):

$$CN = \frac{1{,}000}{S + 10} \qquad (10\text{-}3)$$

or

$$S = \frac{1{,}000}{CN} - 10 \qquad (10\text{-}4)$$

where S = potential infiltration, in.

CN is related to hydrologic soil-cover complex, i.e., a combination of specific soil and specific cover. The soils in the U.S. are classified into four groups according to their hydrologic properties.[2] Group A soils have low runoff potential and high infiltration rates. Group D soils have high runoff potential. Groups B and C have intermediate potentials.

The index of watershed wetness is the Antecedent Moisture Condition (AMC). Three levels of AMC are used:

AMC - I: Lowest runoff potential. The watershed soils are dry enough for satisfactory plowing or cultivation to take place.

AMC - II: The average condition.

AMC - III: Highest runoff potential. The watershed is practically saturated from antecedent rains.

The AMC for feedlots can be estimated from 5-day antecedent rainfall by the use of Table 10-5, which given the rainfall limits for "dormant season." No upper limit is intended for AMC - III (see Figure 4-9, Ref. 2).

Table 10-5. SEASONAL RAINFALL LIMITS FOR VARIOUS ANTECEDENT MOISTURE CONDITIONS

AMC group	Total 5-day antecedent rainfall (in.)	Total 5-day antecedent rainfall (cm)
I	< 0.5	< 1.3
II	0.5-1.1	1.3-2.8
III	> 1.1	> 2.8

Using feedlot runoff data from various authors[3,6] and Eqs. (10-2) and (10-3), the amount of runoff from a given rainfall amount is computed for the three antecedent moisture conditions, as shown in Table 10-6.

Table 10-6. RUNOFF (IN INCHES) FROM FEEDLOT SURFACES FOR VARIOUS ANTECEDENT MOISTURE CONDITIONS

	Precipitation (in.)					
Runoff condition	0.5	1.0	1.5	2.0	2.5	3.0
AMC III						
Surfaced	0.318	0.792	1.282	1.776	2.272	2.770
Unsurfaced	0.258	0.707	1.185	1.673	2.166	2.660
AMC I and II						
Surfaced	0.138	0.505	0.938	1.398	1.871	2.352
Unsurfaced	0.071	0.360	0.741	1.165	1.612	2.072

The following procedure is suggested to calculate runoff from feedlots using the SCS method:

a. Determine feedlot area, which includes feeding pens, sick pens, feed mixing and handling and equipment storage areas, alleys, and other open areas associated with feedlot management. In the absence of actual data, assume total area as 115% of feeding pen area.

b. Select the time period for which storm data are required. While no simple procedure is available to determine the representative storm periods for a given location, storm data during the past 3 years may be used to approximate the most recent trends in precipitation. Lesser time intervals may be used if the records show no substantial deviation from expected norms in precipitation patterns. Select precipitation data on a daily basis. Express all precipitation in terms of equivalent water by using the ratio of one volume of water to 10 volumes of snowfall.

c. Determine storm rainfall (P) from Step (b) above. For each location, the nearest weather station data may be used unless special rain gages were installed for the location.

d. Determine the amount of runoff for a given storm using data in Table 10-6. If local data permit an accurate determination of CN values, Eqs. (10-2) and (10-3) may be applicable for a given location.

e. Determine runoff (inches or centimeters) by adding runoffs for each of the storms over a given period of time. It is useful to determine monthly values in order to obtain maximum and minimum 30-day runoff volumes. By adding the monthly runoff volumes, annual runoff may be obtained.

f. Calculate total runoff volume by multiplying runoff depth in Step (e) with area of feedlot determined in Step (a). The result may be expressed in volume units (acre-inch to ft^3 or hectare-centimeter to m^3).

10.3.3.2 Example -

An example computation of runoff for a hypothetical feedlot located near the climatological station at International Airport, Kansas City, Missouri, is shown below.

Assume that the feedlot comprises 220 acres (88 ha). Calculate total runoff volume from the feedlot using 1974 climatological data for the location.

The daily precipitation data for the station are presented in Table 10-7. These data may be obtained from any one of the three categories of

Table 10-7. DAILY PRECIPITATION DATA (INCHES) FOR KANSAS CITY, MISSOURI - 1974

Date	J	F	M	A	M	J	J	A	S	O	N	D
1	0.04	0	0	T[a]	0	0	0	T	0.71	0	0	T
2	0.07	T	0	0	0	0	0	0	0.29	0	0.15	0
3	0	T	0.25	0.24	0	0.06	1.12	0	0	0	1.07	0
4	0	0	T	0.04	0	0.03	T	0	0	T	0.04	0
5	0	0.02	0	0	0	0	0	0	0	0.44	0	0
6	T	T	0	0	0	0.96	0	0.62	0.02	0.50	0	0.35
7	0	T	0	T	0.06	0.01	0	0.03	0	0	0	0.02
8	0.12	T	0.30	0	0	0.72	0	0	0	0	0	0
9	0.20	T	0	0	0.13	0.02	0	0.13	0	0	0.15	0
10	0.03	0	0.49	T	0.52	0	0	0	0	0	0.15	0
11	0	0	0.03	0.08	0.14	0.32	0	0	0	0.46	0	0.40
12	0	0	0.01	0	0	0	0	0	0.07	0.04	0	0
13	0	0	0	0.03	1.02	0	0	0	0	1.26	T	0
14	0	0	0	0	0.22	0	0	0	0	0	T	0.16
15	0	0	0.03	T	0	T	0	0.01	0.04	0	0	T
16	0	0	0	T	0.77	0	0	0.88	0	0	0	T
17	0	0	0	0	3.13	0	0	0.25	0	0	0	T
18	T	0.29	0	T	3.21	0	0	0	0	0	0	T
19	0.02	0	T	0	0	0.04	0	0.03	0	0	0	T
20	0.12	0	0.01	0.66	0	0	0	0	0	0	0	T
21	T	0.78	0	0	0.05	0	0	0.12	0	0	0	0
22	0.12	T	T	0	0.09	0	T	0.88	0	0	0	0
23	0	0.03	0.05	0	0.01	0	0	0	0	0.10	T	T
24	0	0	0	0	0	0	0	0	0	T	0	0.11
25	0	0	0	0	0.29	0	0.01	0	0	0.04	0	0
26	0.30	0	0	0	0	0	0	0	0	T	0	0.02
27	0.02	0	0	T	T	0	0	0.12	0	0	0	T
28	0.01	0	0	0.28	T	0	0	0.56	T	0.33	T	0
29	0	-	0.01	1.60	T	0	0	0	T	0	0.03	0.01
30	0	-	0	0.01	0.43	0	0	0.08	0	3.48	0.03	0.27
31	0	-	0	-	0	-	0	1.27	0	0.57	-	0.18
Total	1.05	1.12	1.18	2.94	10.07	2.16	1.13	4.98	1.13	7.22	1.62	1.52

Annual precipitation: 36.12 in.

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[a] T - trace.

climatological reports discussed earlier (i.e., hourly precipitation data - Missouri; local climatological data - Kansas City, Missouri; and climatological data - Missouri).

Using Eqs. (10-2) and (10-3), and substituting a CN value of 91, Eq. (10-2) becomes:

$$Q = \frac{(Pr - 0.1978)^2}{(Pr + 0.7912)} \qquad (10\text{-}5)$$

Table 10-8 was prepared using data in Table 10-7 and Eq. (10-5) for each daily event.

The results in Table 10-8 show that rainfall of less than 0.4 in. produces no runoff. Only 37 calculations were involved for the 1974 data. On an annual basis, the results in Tables 10-7 and 10-8 show that 36.12 in. precipitation resulted in a runoff of 14.58 in. On a 220-acre feedlot, the annual runoff volume thus amounts to 267.30 acre-ft (32.60 ha-m). This is equivalent to an annual runoff volume of 87 million gallons or 0.326 million cubic meters.

10.3.3.3 Empirical regression method -

The general empirical relation between rainfall and runoff developed in literature for feedlots may be expressed as follows:

$$Q = L \cdot Pr - B \qquad (10\text{-}6)$$

where Q = runoff, cm (in.)

Pr = precipitation, cm (in.)

L = regression coefficient (slope)

B = regression constant, cm (in.) (intercept)

The regression constant B may be regarded as that amount of precipitation that is stored on the feedlot surface and hence not available as runoff. The coefficient L may be similarly regarded as a fraction of the net available precipitation (i.e., total precipitation minus total storage and other seepage losses) that results in surface runoff. Under dry conditions, the value of B may be higher than that under wet conditions. The value of L may be higher for surfaced lots than for unsurfaced lots.

Table 10-8. ESTIMATED RUNOFF (INCHES) FOR KANSAS CITY, MISSOURI - 1974

Date	J	F	M	A	M	J	J	A	S	O	N	D
1												
2												
3				0.0017			0.4450		0.1748		0.4087	
4									0.0969			
5										0.0476		
6						0.3317		0.1263		0.2568		0.0203
7												
8			0.0096			0.1804						
9												
10			0.0666		0.0792							
11						0.0134				0.0549		0.0343
12												
13					0.0175					0.5501		
14												
15												
16					0.2097			0.2785				
17					2.7872			0.0712				
18		0.0079			2.8665							
19												
20				0.1482								
21		0.2157										
22								0.2785				
23												
24												
25					0.0079							
26												
27												
28				0.0025				0.0971		0.0156		
29				1.2806								
30										2.5222		0.0049
31								0.5577		0.3159		
Total	0	0.2236	0.0762	1.4330	5.9680	0.5255	0.4450	1.4093	0.2717	3.7631	0.4087	0.0595

Annual runoff: 14.5836 in.

The reported values of L and B are based on the least-squares fit of experimental data to Eq. (10-6) under different climatic and geographic conditions. Consequently, significant variations may be found in these data.

Kreis et al.[7] have determined the values of L and B for a commercial feedlot in central Texas having an annual precipitation of 37 in. to be 0.5 and 0.124, respectively. Wells et al.[8] showed similar values for southwestern cattle feedlots. They obtained L and B of 0.746 and 0.192 for surfaced feedlots and 0.345 and 0.309 for unsurfaced lots.

Loehr[9] reviewed literature for feedlot runoff and evaluated the regression coefficients L and B in Eq. (10-6) for various conditions. Loehr's results are shown in Table 10-9.

Table 10-9. RUNOFF AND RAINFALL RELATIONSHIPS ON BEEF CATTLE FEEDLOTS[9]

		Minimum rainfall to produce runoff		
L	B	(cm)	(in.)	Conditions
0.945	0.34	1.0	0.4	Surfaced lot
0.882	0.37	1.0	0.4	Unsurfaced lot
0.53	0.14	1.0-1.3	0.4-0.5	3 to 9% slopes
0.93	0.41	1.2	0.45	1968 runoff
0.45	0.05	1.3	0.5	1969 runoff
0.49	0.06	1.3	0.5	1970 runoff
0.50	0.12	0.5-6.8	0.2-0.32	1969 to 1970

The following procedure is suggested to determine the runoff volume using the Regression Method:

a. Determine feedlot area and precipitation for a given site using the procedure described in SCS method, Steps (a), (b), and (c).

b. Determine the regression coefficients for the site conditions in the area from local experimental data or other reported values applicable to the area. Otherwise, assume the following ranges of values:

Site condition	Moisture condition	L	B (in.)	B (cm)
Surfaced lot	Wet	0.5-0.95	0.0-0.2	0.0-0.5
Surfaced lot	Dry	0.5-0.95	0.2-0.4	0.5-1.0
Unsurfaced lot	Wet	0.5-0.95	0.0-0.3	0.0-0.8
Unsurfaced lot	Dry	0.5-0.95	0.3-0.5	0.8-1.0

c. Calculate runoff (centimeters or inches) using Eq. (10-6) and data in Steps (a) and (b) above.

d. Calculate monthly or annual runoff using the procedure described in SCS method, Step (e).

e. Calculate total volume of runoff by multiplying runoff depth (Step (d)) with feedlot area (Step (a)).

10.4 POLLUTANT CONCENTRATION IN FEEDLOT RUNOFF

Some of the reported data on feedlot runoff characteristics are presented in tabular form in Tables 10-10 and 10-11. As indicated earlier, the range in concentrations is wide. The handbook user has two alternatives.

1. He may use the range of values given in the tables as guidelines for selecting concentrations for livestock operations in his area. If this alternative is selected, he should use values at both the lower and upper range of the data which appear to represent his area, and estimate a probable range of loads rather than an assumed average load.

2. He may use data obtained on a current basis in his area. If this alternative is selected, he should be careful to determine and specify the local range of values. This second alternative is preferred over alternative (1).

Essentially no data exist for concentrations of pollutants in runoff from hog lots, poultry ranges, and dairy and sheep lots. In lieu of actual local data (alternative (2) above), the beef cattle runoff data can be used as guideline data for other livestock. Pollutant concentrations in runoff are relatively insensitive to the quantity of waste exposed to the runoff, particularly if the lot surface has been in use for extended periods. It is not proper to attempt to factor down the concentrations in proportion to relative rates (hogs versus beef cattle, e.g.) of animal waste deposition on feedlot surfaces. If actual data are not available, pollutants in runoff from lots other than beef cattle feedlots should be assumed to lie within the ranges reported for beef cattle.

Table 10-10. BEEF CATTLE FEEDLOT RUNOFF CHARACTERISTICS

	Total solids	Suspended solids (mg/ℓ)	COD (mg/ℓ)	BOD_5 (mg/ℓ)	Org-N (mg/ℓ)	NH_3-N (mg/ℓ)	NO_3-N (mg/ℓ)	Total N (mg/ℓ)	Total P (mg/ℓ)	Alkalinity (mg/ℓ as $CaCO_3$)	pH	Ref. no.
Nebraska												
Snowmelt runoff	3.0-19.8[a]	-	14,100-78,000	1,600-7,900	-	270-2,028	0-80	1,429-5,765	7-750	-	6.7-7.6	10
Rainfall runoff	0.024-1.74[a]	-	1,300-8,200	370-600	-	26-82	0-17	65-555	14-47	-	6.7-9.4	10
Texas												
Dirt lots	-	-	2,964-28,000	1,150-3,210	6-434	2-100	0-163	-	-	70-1,600	7.1-7.95	8
Concrete lots	-	-	5,000-48,000	2,400-10,000	35-797	33-774	0-1,270	-	-	86-2,600	5.6-7.3	8
Texas												
Dirt lot	3,100-28,900[b]	745-17,702	1,440-16,320	1,075-3,450	31-495	4-173	0-2.3	35-668	21-223	-		7
Kansas												
Nonsurfaced lot	-	1,500-10,500	1,900-8,900	216-1,010[c]	-	1-65	0.1-6	50-540	-	-		11
Concrete lot	-	1,400-12,000	2,760-19,400	314-2,200[c]	-	1-140	0.1-11	94-1,000	-	-		11

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[a] Percent.

[b] Mg/ℓ.

[c] Calculated using a COD/BOD ratio.

Table 10-11. RUNOFF CHARACTERISTICS FROM CATTLE FEEDLOTS IN KANSAS*12/

	Concrete	Nonpaved
Ammonia-N		
Winter	1.3-7.0 mg/ℓ	1.0-3.8 mg/ℓ
Spring-fall	20-77 mg/ℓ	13-45 mg/ℓ
Summer	50-139 mg/ℓ	26-62 mg/ℓ
NH_3-N: Kjeldahl-N, %		
Winter	0.01-0.05	0.02-0.6
Spring-fall	0.3-0.4	0.06-0.2
Summer	0.1-0.4	0.1-0.3
Nitrite-N		
October-November	1.0-5.0 mg/ℓ	1.0-2.3 mg/ℓ
July-August	1.0-6.0 mg/ℓ	1.0-7.0 mg/ℓ
Suspended solids		
July-August		
Moist - 1 in/hr	6,000 mg/ℓ	5,000 mg/ℓ
Dry - 0.4 in/hr	3,000 mg/ℓ	1,500 mg/ℓ
Dry - 2.5 in/hr	1,400 mg/ℓ	2,000 mg/ℓ
Wet - 2.5 in/hr	3,000 mg/ℓ	3,000 mg/ℓ
Wet - 0.3 in/hr	12,000 mg/ℓ	10,500 mg/ℓ
October-November		
Wet - 1 in/hr	2,000 mg/ℓ	1,800 mg/ℓ
Wet - 0.5 in/hr	2,500 mg/ℓ	-
Bacterial densities (in millions of organisms per 100 ml), 70% limits		
July-November		
Total coliform	33-348	22-348
Fecal coliform	35-240	8-79
Fecal streptococci	13-240	8-79

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* Kansas data shown here are typical for Midwestern states. These values tend to increase in the West and decrease in the East.

Measurements of pollutant concentrations indicate trends helpful in selecting data for load calculation. These trends are: (a) runoff from winter thawing conditions produce greater concentrations of pollutants than that produced by rainfall under warmer conditions, and (b) runoff from concrete (surfaced) feedlots contain higher concentrations of COD, BOD, and nitrogen than that from unsurfaced feedlots. BOD concentrations in runoff from surfaced lots are approximately twice those from unsurfaced feedlots.

10.5 POLLUTANT DELIVERY RATIO, FL_d

The proportion of on-site-generated pollutants in feedlot runoff delivered to streams has not been documented. Delivery ratios have therefore been developed by the study group in consultation with EPA personnel. Literature information on sediment delivery and the system developed and presented in Section 3.0 are the basis for development of values for FL_d. The following additional considerations were involved:

1. The majority of the pollutant load is carried away in the first part of the runoff hydrograph.

2. Feedlot solids are fine textured and tend not to settle out of overland runoff.

3. Observation has shown that buffer strips have limited value for permanent retention of runoff-contained sediment.

The delivery ratio is therefore expected to be higher than delivery ratios for sediment from similarly located cropland. Recommended delivery ratios are:

Case I - Feedlot near (within 0.2 km, 0.1 mile) a permanent unobstructed waterway: $FL_d \geq 0.9$.

Case II - Feedlot located more than 0.2 km (0.1 mile) from stream or unobstructed waterway: $FL_d = 0.7$ to 0.9.

10.6 FEEDLOT AREA, A

The A factor in Eq. (10-1) is determined in effect by multiplying feedlot populations by stocking rates and proportioning areas among specific lots. In practice, A is determined by approximation from data from various sources such as: "Cattle on Feed,"[13] state departments of agriculture and state environmental or health agencies, design manuals, and Special Census of Agriculture Reports.[14] Some statistics on beef cattle feedlots are shown in Table 10-12.

Table 10-12. NUMBER OF CATTLE FEEDLOT AND FED CATTLE MARKETED-- IN SMALL LOTS, BY STATES (1974)[14,a]

State	Under 1,000 head feedlot capacity		Total all feedlots	
	Lots (No.)	Cattle marketed (1,000 head)	Lots (No.)	Cattle marketed (1,000 head)
Arizona	6	1	47	895
California	28	13	167	2,002
Colorado	425	131	613	1,892
Idaho	502	11	574	344
Illinois	14,445	755	14,500	850
Indiana	10,477	336	10,500	361
Iowa	31,835	2,710	32,000	3,097
Kansas	5,660	400	5,800	2,240
Michigan	1,667	177	1,700	242
Minnesota	10,970	795	11,020	864
Missouri	11,979	348	13,000	400
Montana	211	26	276	187
Nebraska	14,510	1,330	14,970	3,355
New Mexico	7	1	48	355
North Dakota	880	53	900	84
Ohio	8,175	328	8,200	386
Oklahoma	358	36	400	566
Oregon	305	22	331	120
Pennsylvania	5,997	114	6,000	123
South Dakota	9,123	407	9,200	585
Texas	1,001	85	1,200	3,899
Washington	165	33	186	301
Wisconsin	7,084	149	7,100	180
23 States	135,810	8,261	137,732	23,334

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[a] Number of feedlots under 1,000 head capacity is number of lots operating at end of year.

The feedlot area should include area devoted to feed handling and mixing, sick pens, alleys and equipment storage. Beef cattle lots are typically 15% larger than the feeding pen area.

The following procedure illustrates how A may be calculated. Data for Nebraska reported in "Cattle on Feed,"[13/] have been used to estimate average areas and total area of small feedlots.

Data reported, for feedlots with < 1,000 head:	
Number of lots	14,510
Cattle marketed annually	1,330,000
Data assumed:	
Stocking rate	23 m^2/animal 250 ft^2/animal
Turnover rate	2/year
Calculated data:	
Average area/lot	0.1 ha (0.26 acre)
Total pen area	1,525 ha (3,800 acres)
Total production area (Pen area x 1.15)	1,754 ha (4,370 acres)

10.7 METHODS FOR DEVELOPING FEEDLOT STATISTICS

Several options are available to the user to evaluate the parameters in loading function for feedlots. The following discussion is intended to facilitate the selection and use of appropriate data and data sources, especially when the direct use of field data is not possible.

The data on the total number of livestock by county and state are published in Census of Agriculture statistics, by the U.S. Department of Agriculture. The census data also show the number of livestock "on feed." State summaries of livestock on feed, by capacity of feedlots, are published by the Agricultural Statistics divisions of the State and U.S. Departments of Agriculture. A large fraction of the published state data is related to beef cattle feedlots. State data sources contain livestock data on a county basis. The locations of feedlots within a given region can only be obtained by reference to state/local statistics. If the data specify the total number of animals marketed, a turnover rate should be used to compute yearly livestock numbers. If the data specify animal on feed or on hand as of a certain date, then the turnover rate is not considered.

The distribution data will also help to assess probable distances to given surface waters, and hence, the amounts of pollutants delivered.

The areas of feedlots may be obtained either from actual inventories of feedlot data for a region, or estimated by using statistical projections of sampled sites for which data exist. An indirect method of estimating feedlot area involves a knowledge of animal type, total number of animals, and stocking rates (area per animal). The stocking rate differs for different livestock types and usually falls within the following ranges:

Beef cattle - 100 to 400 ft^2 (9 to 36 m^2)
Dairy cattle - 80 to 400 ft^2 (7 to 36 m^2)
Swine, breeding - 100 to 250 ft^2 (9 to 23 m^2)
Swine, growing-finishing - 200 to 1,500 ft^2 (18 to 135 m^2)
Sheep - 15 to 100 ft^2 (1 to 9 m^2)
Turkeys, range - 100 to 200 ft^2 (9 to 18 m^2)

Feedlot surface conditions, climatic conditions, and other factors determine the actual stocking rate within the above range.

The required data on feedlot numbers, areas, and locations can thus be developed from several sources of data as indicated by the following cases:

Case 1. Little or No Local Data Available

Beef Cattle

Given Data -

- Number of small lots ($<$ 1,000 head), by state, Census of Agriculture statistics.
- Total number of cattle, by county, Census of Agriculture statistics.
- Turnover rate of 2/year.

Estimated Data -

- Average lot size (small lots) equals number of cattle per turnover divided by number of lots.
- Average lot area equals average size times stocking rate selected from range given above (100 to 400 ft^2/animal, 10 to 40 m^2/animal).

- Number of lots by county, i.e., number of small lots per county equals number of small lots in state times total cattle in county divided by total cattle in state.

- Delivery ratio: in absence of information on distance to watercourses, use 0.9.

Hogs

Given Data -

- Hog population, by county, Census of Agriculture statistics.
- Sixty percent of hogs in small lots (< 2,500 head per lot).
- Fifty percent of all hogs are raised under roof.
- Stocking rate, in range of 200 to 1,500 ft^2/animal (20 to 140 m^2/animal).
- Delivery ratio: 0.9.
- Turnover rate: 2/year.

Estimation -

- Total lot area, in county equals 0.15 times total county population times stocking rate. Convert to hectares or acres.

Turkeys

Given Data -

- Total population, by county, Census of Agriculture statistics.

Assumptions -

- Eighty percent of turkeys on range.
- Stocking rates, in the range of 100 to 200 ft^2/bird (10 to 20 m^2/bird)
- Delivery ratio: 0.9.
- Turnover rate: 2/year.

Estimations -

- Lot area equals 0.4 times county population times stocking rate. Convert to hectares or acres.

Sheep

Given Data -

- Total population, by county, Census of Agriculture statistics.

Assumptions -

- Eighty-five percent in open lots.
- Stocking rates range from 15 to 100 ft^2/animal (1.5 to 10 m^2/animal).
- Delivery ratio: 0.9.
- Turnover rate: 2/year

Estimation -

- Lot area, in county equals 0.4 times county population times stocking rate. Convert to hectares or acres.

Case 2. Local, Actual Data Available

In an idealized case, perhaps for a small watershed, data on feedlot sizes, locations, and areas will either be a matter of record, or can be readily obtained by questionnaire or other means. Feedlots covered by NPDES permits should be subtracted from the total, and other lots with runoff control also deleted. The remainder will be counted as nonpoint sources.

Given Data -

- Number of small lots and livestock population per lot, local data.
- Area of each lot, local data.
- Location of each lot from the nearest water course, actual data of record.

Assumptions -

- Delivery ratios:
  - 0.9 (less than 0.1 mile or 0.2 km from stream).
  - 0.7 (greater than 0.1 mile or 0.2 km from stream).

Case 3. Combination of Local Data and Area-Wide Data

Determination of area, location, and livestock population of small feedlots at the local level (county/state) involves a search of various data sources--including an evaluation of unpublished data of record. State departments of agriculture--agricultural statistics divisions, animal husbandry divisions of state agricultural extension services, agricultural economics departments of land grant universities, state environmental protection agencies, state public health departments, county tax assessors' offices, and state revenue departments are some of the sources of local data. Because of the variations in jurisdiction in different state governments, the local planner responsible for making the assessment of nonpoint source pollution from livestock in confinement should ascertain the availability of data from appropriate sources within the state.

The county based livestock population data are published by the U.S. Department of Agriculture--Census of Agriculture. However, areal data for small lots are not available directly from the census data. An example calculation of the area, delivery ratio, and livestock population in small beef cattle feedlots from a mix of local and area-wide data is shown below:

Given Data -

- Number of livestock, county, Census of Agriculture statistics.
- Number of small lots (< 1,000 head) by county, from state agricultural extension division.
- Number of cattle in small lots, by county, from state agricultural extension division.
- Stocking rates--local data from land grant university, agricultural economics department.
- Turnover rate equals 2/year.

Assumptions -

- Delivery ratio--for lots less than 0.1 mile (0.2 km) from stream: 0.9; for lots more than 0.1 mile (0.2 km): 0.7.
- None of the small lots reported runoff control.

Estimation -

- Area of small lots equal stocking rate time either (1) number of cattle marketed from small lots divided by 2, or (2) number of cattle on feed as of January 1.

10.8 ACCURACY OF PREDICTION

The major uncertainties in the loading function are pollutant concentrations and delivery ratios. If reliable data on pollutant concentration, feedlot areas by source, and precipitation-runoff are obtained for the local conditions, the accuracy of prediction can be reasonably good. The pollutant delivery ratio tends to be quite high for existing feedlots located near streams. For others, the determination of FL_d from local data accurately will improve the prediction accuracy. Using average, long-term conditions, the range of accuracies expected are presented in Table 10-13.

Table 10-13. ESTIMATED RANGE OF ACCURACY FOR PREDICTING POLLUTANT LOADS FROM FEEDLOTS

Pollutant	Estimated value (kg/ha/year)	Probable range (kg/ha/year)
BOD_5	10,000	2,000-50,000
N-total	600	100- 3,000
N-available	50	10- 200
P-total	250	50- 1,000
Suspended solids	10,000	5,000-25,000

10.9 PROCEDURE FOR COMPUTING POLLUTANT LOADING

The following step-by-step procedure is suggested to compute the potential pollutant loading from feedlots, based on the discussion of loading function presented in this section. It is assumed that the regional boundary is established for assessing the loadings.

1. Determine the number of feedlots.

2. Determine the number and kind of livestock in each feedlot.

3. Determine the area A of individual and total feedlots using either actual data or procedures outlined earlier in this section.

4. Obtain precipitation data Pr for the time interval required, i.e., storm event, 30-day period, year, from local weather stations, or from the National Climatic Center, U.S. Weather Bureau.

5. Compute runoff volume Q from options presented above.

6. Determine the range of pollutant concentrations in feedlot runoff either from local records or from Tables 10-10 and 10-11.

7. Determine the value of the delivery ratio FL_d from a knowledge of feedlot location in relation to the stream or from drainage density in the basin.

8. Determine load of each pollutant by using Eq. (10-1), Items 3, 5, 6, and 7 above.

9. Convert results to annual average, daily value, expressed as a range of loads consistent with ranges of input data on pollutant concentrations.

10.10 EXAMPLE

An open, unsurfaced feedlot in eastern Kansas has an area of about 5 acres and carries on an average 900 head of cattle at any given time. The feedlot is located 1/4 mile from a small creek which eventually discharges into the Kansas River. Assuming that the BOD_5 concentration of feedlot runoff ranges from 5,000 to 10,000 mg/liter and a monthly precipitation of 6 in., calculate the daily load delivered to the creek during the 30-day period.

In the absence of precipitation event data, interpolation of precipitation and runoff data presented in Table 10-7 and Table 10-8 for the months of August and October show an average runoff of 2.5 in.

The delivery ratio is estimated to be 0.8 for a silt-clay soil and a drainage density of 4 miles/sq mile.

Thus the BOD_5 loading for a concentration of 5,000 mg/liter is, from Eq. (10-10),

$$Y(BOD)_{FL} = \frac{0.23 \times 5{,}000 \times 2.5 \times 0.8 \times 5}{30}$$

$$= 380 \text{ lb/day}$$

For BOD_5 of 10,000 mg/liter, the loading is $Y(BOD)_{FL} = 760$ lb/day.

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SECTION 11.0

TERRESTRIAL DISPOSAL

11.1 INTRODUCTION

Solid wastes and slurries disposed on landfill sites have a significant potential to pollute local groundwater aquifers, and thus to pollute nearby surface streams. Water that infiltrates landfill cover soil may produce leachate, in quantity dependent on precipitation, antecedent moisture condition of the landfill soil, solid waste composition, and groundwater hydrology. The absorptive capacity of the landfill, its areal extent, and the amount of recharge water available for infiltration are the key parameters that determine the total volume of leachate. Open dumps can be expected to produce more leachate than sanitary landfills.

Leachates contain significant concentrations of BOD, COD, iron, chlorides, and nitrates. Where toxic wastes have been discharged, the leachates also contain heavy metals and toxic substances. The character of leachate, thus, is highly sensitive to the type of waste in the land disposal site, the age of the site, and the temperature and moisture content of the fill.

Once a leachate is produced, it may react with soil constituents at rates depending upon the reactivity of the substances in the leachate. The concentration and the total quantity of a given pollutant in the leachate may be attenuated by physical-chemical processes and biological processes. The attenuation may proceed both in saturated and unsaturated zones of the soil, as shown in Figure 11-1.

The degree of attenuation cannot be predicted with reasonable accuracy. Soil, especially in the unsaturated zone, is probably most important in this attenuation. The leachate is also in effect attenuated by dilution in groundwaters, and groundwater movement through underground aquifers results in reactions (chemical reaction, physical absorption-desorption,

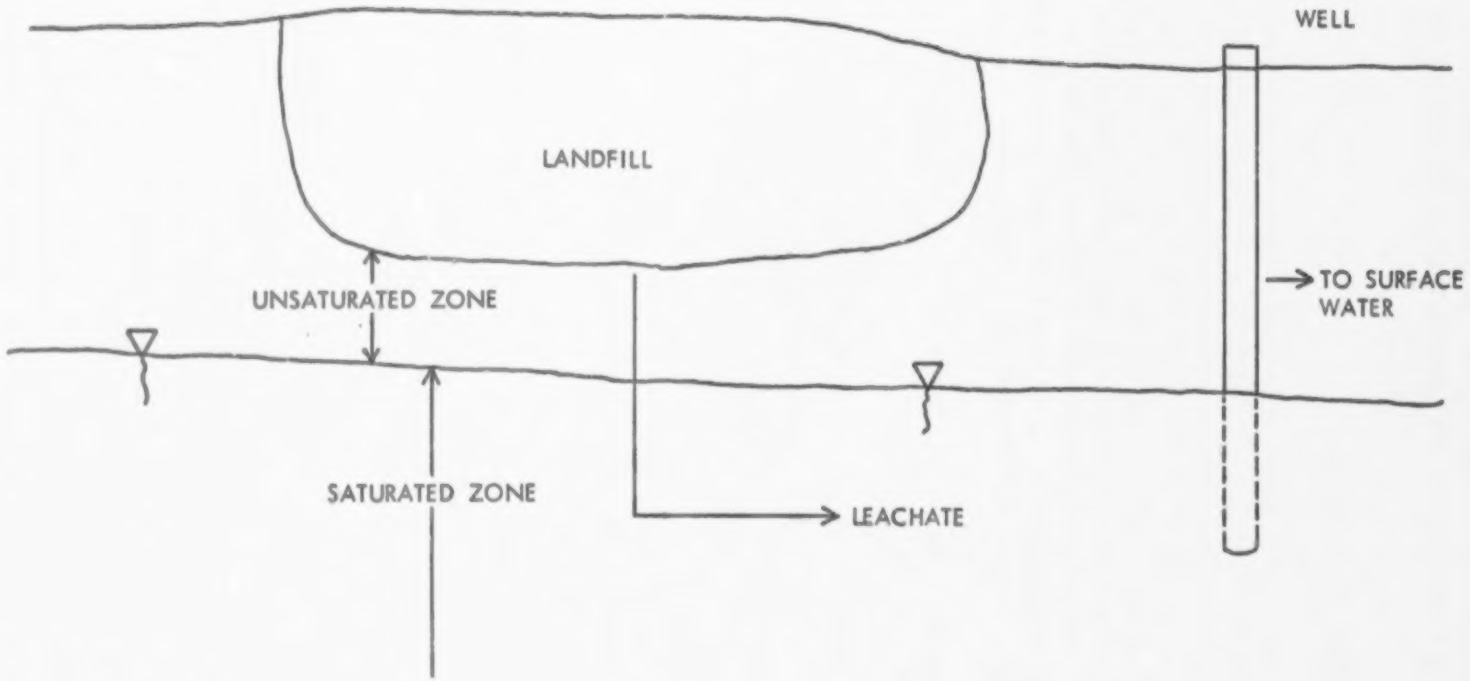
WELL
LANDFILL
TO SURFACE WATER
UNSATURATED ZONE
SATURATED ZONE
LEACHATE

Figure 11-1. Leachate flow through path through zones where attenuation may be effected.[1]

and biological reactions) which degrade the pollutant, equilibrate it with geological strata, and possibly transform certain constituents to insoluble minerals.

11.2 LOADING FUNCTION FOR LANDFILLS

The actual loading rate for a given pollutant cannot be made without knowledge of soil properties, hydrology and landfill characteristics. It is not possible, therefore, to predict the extent of pollutant load that is actually transmitted to a stream with presently available data. Approximate at-site leachate emission rates can be determined from the knowledge of percolation rates and pollutant concentrations expected from landfill sites. If a site is located close to a surface water course, the at-site emission rate may be close to the stream loading rate. If the site is distant from surface waters, the emissions may be markedly attenuated.

The loading function for a given pollutant is thus given by:

$$Y(i)_{LF} = a \cdot C_Q(i)_{LF} \cdot p \cdot LF_d \cdot A \qquad (11\text{-}1)$$

where $Y(i)_{LF}$ = average loading rate of pollutant i, kg/year (lb/year)

p = percolation rate, cm/year (in/year)

$C_Q(i)_{LF}$ = average concentration of pollutant i, in leachate at site, mg/liter

a = a dimensional factor, 0.1 metric (0.23 English)

LF_d = leachate delivery ratio for landfill

A = area of landfill, ha (acres)

The delivery ratio, LF_d, varies in theory from 0 (no delivered pollutant) to 1.0 (100% delivery). Values of LF_d are a matter of local judgment.

Pollutant concentrations, $C_Q(i)_{LF}$, vary with the site characteristics and vary widely even within a given region. A range of reported values is presented in Table 11-1.[1/] Pollutant concentration is influenced by the amount of leachate produced. Leachate volume is in turn influenced by several factors including surface cover, subsurface lining characteristics of the landfill, and climatic conditions. Percolation rate may, in some cases, be higher or lower than leachate flow rate. Published average annual percolation rates for the United States are shown in Figure 11-2.[2/]

Table 11-1. CHEMICAL CHARACTERISTICS OF LEACHATES[1/]

Constituent	Concentration, mg/l
BOD_5	80 - 33,100
COD	150 - 71,000
Organic nitrogen	50 - 200
Nitrate (as N)	0.2 - 1,300
Ammonia (as N)	0 - 1,000
Sulfate	28 - 3,770
Chloride	4.7 - 2,467
Iron (total Fe)	0 - 2,820
Hardness	0 - 22,800
Copper	0 - 9.9
Zinc	0 - 370
Manganese	0.1 - 125
Lead	0.1 - 2
Cadmium	0.03 - 17

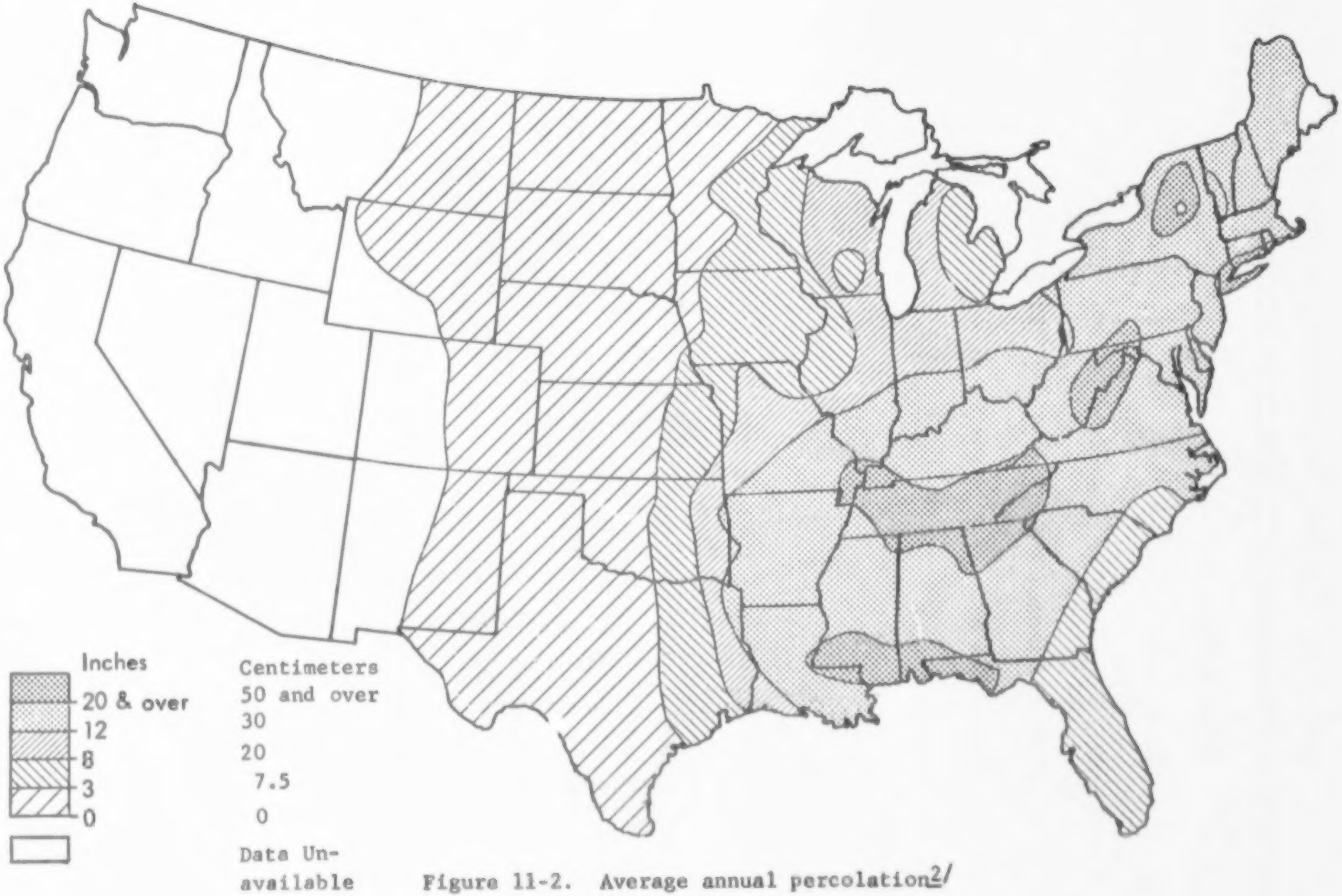
Inches
20 & over
12
8
3
0
Centimeters
50 and over
30
20
7.5
0
Data Un-
available

Figure 11-2. Average annual percolation2/

The percolation map indicates potential leachate quantities throughout the country. Most severe leachate problems are expected east of the Mississippi and in the Pacific Northwest. For conditions east of the Mississippi, where an average of 30 cm (12 in.) of percolation and 80,000 ha (200,000 acres) of landfill surface were assumed, the net annual amount of leachate produced has been estimated to be 246 million $meters^3$ (65 billion gallons), or 3,000 m^3/ha (325,000 gal/acre) of landfill surface.[1/] This amount would be reduced by 50% or more with proper cover and vegetation on the site. The percolation map (Figure 11-2) should serve principally as a guideline for local analysis. For example, percolation in areas which experience highly seasonal precipitation will not conform well to data on the map, and its use would give results in error. Landfill sites should therefore be analyzed on a local or an areal basis, and percolation data developed should take into account engineering practice in the area as well as climatological and hydrological data specific to the area. In this regard, it must be emphasized that old sites as well as current sites are to be included in the analysis.

11.3 PROCEDURE FOR COMPUTING LANDFILL POLLUTANT LOADINGS

In order to compute pollutant loadings from landfill leachates in a region, the following data are needed:

Landfill characteristics including number, size, location, age, and surface area.
Percolation and leachate data.
Pollutant concentration data.
Leachate delivery ratio.

The availability of specific data will dictate the degree of accuracy one can achieve in computing the loading rates. Thus, several options are open to determine the pollutant loadings in a given region.

11.3.1 Landfill Characteristics Including Number, Size, Location, Age, and Surface Area

The 1968 National Survey[3/] published extensive statistics on community solid waste practices by region. Waste Age[4/] made a telephone survey of solid waste disposal practices by region. These reports, while estimating the number and area of sites, are too broad for use in a local situation. Local and state health departments should be consulted for specific site information.

11.3.2 Percolation and Leachate Data

Case I - When the landfill site is not engineered as a sanitary landfill, i.e., the surface and bottom are not adequately lined with impervious material, the leachate flow rate can reasonably be assumed to be equal to percolation rates typical of the area. Rates indicated in Figure 11-2 may be adequate, but locally specific data are to be preferred. When groundwater recharge occurs during wet conditions or when the groundwater table is shallow, upwelling may occur; calculation of leachate rates will be very difficult in such cases and will be the province of the local engineer. Monitoring stations will be needed to obtain accurate information.

Case II - When the site is engineered to reduce leachate and/or percolation, such as in lined or compacted landfills, considerably smaller amounts of leachate will leave the site. Data on local design conditions and monitored parameters should be obtained to determine the actual rates of leachate production. Sites with similar physical and climatological characteristics and waste constituents should provide reasonably accurate data.

11.3.3 Pollutant Concentration Data

As shown in Table 11-1, the concentrations of pollutants vary greatly. For example, the reported BOD_5 concentration ranges are 2,000 mg/liter to 30,000 mg/liter. The factors affecting leachate composition are complex. There is no simple way to predict the pollutant concentration for given site conditions. Monitored or field data should be obtained for specific situations. In general, leachate from a completed fill where no more waste is being disposed of can be expected to decrease with time.

11.3.4 Leachate Delivery Ratio

Most published studies describe the on-site pollution potential, and not the actual load delivered to a stream. The delivery ratio is thus a research area.

The approach to selection of a delivery ratio should be on a site-by-site basis, with the delivery ratio developed after consideration of the following factors:

1. Proximity of landfill to surface waters.

2. Proximity to subsurface aquifers.

3. Subsurface water quantities, flows, and direction of flow.

4. Quantity of leachate in proportion to aquifer inventories and flows.

5. The attenuating characteristics of soils for the pollutant of concern.

6. The age of the site.

Confidence in the delivery ratio (as well as leachate quantities and pollutant concentrations) can be markedly increased by analysis of groundwaters and soils at strategically located sampling spots.

Selection of a delivery ratio is thus the province of local specialists in hydrology, water and soil chemistry, and landfill design. The delivery ratio should seldom be more than 0.5 save in exceptionally poorly designed and managed dumps. Conversely, a delivery ratio near zero should be accepted only after rigorous examination of site characteristics.

11.4 Accuracy of Predicted Loads

The accuracy of prediction depends upon the accuracy of parameters used in the loading function. For local situations where small areas are involved, the area of landfill can be easily and accurately determined from local data sources. Determination of percolation rates for the area can also be obtained from experimental data and other reported results for similar soil characteristics and precipitation rates. The percolation rate also is dependent upon the engineering design of the landfill site, its age, and groundwater characteristics. Long-term average rates are generally more precise than short-term, yearly averages. The delivery ratio is usually obtained with less certainty. The delivery ratio can usually be estimated to be near zero for small leachate rates. At high rates the uncertainty in the delivery ratio becomes greater. Concentrations of pollutants in the leachate are extremely variable and are subject to greater fluctuation than other parameters. Consequently, greater error is introduced in the prediction even if other parameters are accurately estimated. The expected range of pollutant loads is shown in Table 11-2. The ranges were estimated on the assumption that some actual site data are available, and that actual characteristics have been evaluated in estimating load; i.e., the range of values presented in Table 11-1 has not been used in the estimations.

Table 11-2. ESTIMATED RANGE OF PREDICTED LOADS FOR VARIOUS POLLUTANTS IN LEACHATES IN LANDFILLS

Pollutant	Estimated value (kg/ha/year)	Range of predicted values (kg/ha/year)
BOD_5	10,000	1,000-100,000
COD	20,000	2,000-200,000
Nitrogen - Total	500	50-5,000

11.5 EXAMPLE

A well engineered sanitary landfill operating during the past 5 years is located in eastern Kansas where the annual precipitation is 36 in/year. The site has a total area of 35 acres and is located about 1 mile from a major river. The rate of percolation is estimated, from local data on rainfall plus landfill surface characteristics, to be 1.5 in/year through the fill material, which is primarily composed of municipal refuse. Leachate from a test well located on-site was analyzed during high flow period, with the following results:

BOD_5 = 8,000 mg/liter

COD = 12,000 mg/liter

pH = 6.3

Alkalinity as $CaCO_3$ = 3,620 mg/liter

Chloride as Cl = 284 mg/liter

NH_4-N = 84 mg/liter

Assuming that the leachate directly enters the river, calculate the pollutant loadings for BOD_5, chlorides, and nitrogen.

Site data and engineering features of the landfill were used by local engineers to arrive at a delivery ratio in the range of 0.05 to 0.2. Assuming a LF_d value of 0.1 in Eq. (11-1), the computed loading rates are shown in Table 11-3.

Table 11-3. POLLUTANT LOADING RATES IN EXAMPLE

Pollutant	Annual load (lb/year)	Daily load (lb/day)
BOD_5	9,660	26.5
Chloride	343	0.94
Nitrogen (NH_4-N)	101	0.28

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SECTION 12.0

BACKGROUND POLLUTANT LOAD ESTIMATION PROCEDURES

12.1 INTRODUCTION

Nonpoint pollution loads can arise from land which has not been disturbed by man's activities. Such loads, referred to as "background" loads, represent natural nonpoint emissions, and have a significant effect upon surface water quality. In general, a clear-cut distinction between loads arising from background sources and loads arising from man's land use practices is virtually impossible to achieve, either philosophically or technically. Therefore, one should approach the problem of background pollutant loads somewhat warily, but also firmly. Any estimation of background pollutant loads will have an unavoidable element of arbitrariness.

This section will present estimation procedure options for background pollutant emissions.

Two different approaches are discussed--a stream-to-source approach (Section 12.2) and a source to stream approach (Section 12.3), together with a discussion at the expected accuracy of each method.

12.2 STREAM TO SOURCE METHODS

12.2.1 Options Available

Four options for estimating nonpoint pollution loads emitted from natural background have been developed using the stream to source approach. These options, together with their constraints, are:

Option I - A method of estimating general background loads over large areas. The method utilizes annual average runoff in the area considered and iso-pollutant concentration maps developed for this purpose. The method yields estimates of pollutant loads on an average annual basis, reported on a per day basis. Use of Option I methods should be restricted to areas of minor water basin size (80,000 miles^2) or larger.

Option II - A second method for estimating general background levels over a large area. The method utilizes the iso-pollutant maps as in Option I, but streamflow carrying the pollutant is used rather than average annual runoff. This method can be used to estimate maximum and minimum pollutant loads within a year by utilizing maximum and minimum flows during the year, and represents the stream to source approach. The size restrictions are the same as those for Option I.

Option III - A method for estimating general background levels on a local or small watershed scale. Average annual runoff for the watershed is used. Background pollutant concentrations deemed appropriate from local water quality data are used instead of iso-pollutant maps. This method should be used when considering local nonpoint problems, and will yield estimates of annual average background loads reported on a per day basis. This option uses the same approach as the first one except that provisions are made for the user to use his judgment to define natural background concentrations.

Option IV - A method, applicable to localized areas and to small watersheds, for estimating background loads, based on local data and experience. The method utilizes streamflow data for pollutant transport as in Option II, and local information deemed appropriate concerning background pollutant concentrations as in Option III. This method permits ready estimation of 30 day maximum and minimum loads by considering flow volumes at various times of the year. If a detailed description of natural background over a large area is desired, the area can be subdivided into local units, Option IV applied to each of the units, and the loads computed for each subunit summed over the whole area.

12.2.2 Information Needs for Background Loading Value Equations

The following information is needed for use in the background loading value equations presented below.

Area (A) from which background pollutants are being emitted.

Flow (Q) of water in which background pollutants are transported.

Concentration (C) of pollutants arising in the area and transported by flow.

Conversion factor (a) needed to yield proper dimensional units of pollutant loads.

Methods for obtaining this information for each option, together with descriptions of the loading value equations, are presented below.

12.2.3 Loading Value Equations and Definition of Conversion Factors

Options I and III - Flow as average annual runoff, in centimeters per year (in/year). Average annual runoff can be obtained from standard runoff maps available from the U.S. Geological Survey (National Atlas, Plates 118 to 119), Water Information Center's *Water Atlas of the United States* (Plate 21), or from local records if available.

$$Y(i)_{BG} = a \cdot A \cdot Q(R) \cdot C(i)_{BG} \tag{12-1}$$

where $Y(i)_{BG}$ = yield of background constituent i in kilograms per day (lb/day)* except where noted in Table 12-1

a = dimensional constant; see Table 12-1

A = area under consideration, in hectares (acre)

$Q(R)$ = flow as average annual runoff, in centimeter per year (in/year)

$C(i)_{BG}$ = estimated concentration of background constituent i (see Section 12.4, Figures 12-1 through 12-19)

Options II and IV - Flow as streamflow, in liter per second (cfs). Streamflow data may be obtained from U.S. Geological Survey records, STORET data, U.S. Army Corps of Engineers records, or other records available at the local level. Annual average streamflow should be used when considering background nonpoint emissions on the annual basis. When estimating background emissions at specific times, e.g., 30 day maximum or minimum, the proper streamflows at those times should be used in the computations.

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* If load units of mass per unit area per day are desired, the area A term is not used.

Table 12-1. CONVERSION FACTORS "a" TO BE USED FOR OPTIONS I AND III LOADING VALUE EQUATION: FLOW AS DIRECT RUNOFF, Q(R)

Constituent	Concentration units	Units of flow "Q(R)"	Units of area "A"	Value of "a"	Units of load
All except those below	ppm	cm/year	ha	2.7×10^{-4}	kg/day
		in/year	acre	6.2×10^{-4}	lb/day
Heavy metals	ppb	cm/year	ha	2.7×10^{-7}	kg/day
		in/year	acre	6.2×10^{-7}	lb/day
Radioactivity	picocuries/ℓ	cm/year	ha	270	picocuries/day
		in/year	acre	280	picocuries/day
Coliforms	MPN/100 mℓ	cm/year	ha	2,700	MPN/day
		in/year	acre	2,800	MPN/day

$$Y(i)_{BG} = a \cdot Q(str) \cdot C(i)_{BG} \quad (12\text{-}2)$$

where $Y(i)_{BG}$ = yield of background constituent i , in kilograms per day (lb/day) except where noted in Table 12-2

a = dimensional constant; see Table 12-2

$Q(str)$ = flow as streamflow, in liter per second (cfs)

$C(i)_{BG}$ = concentration of background constituent i (see Section 12.4, Figures 12-2 through 12-20

12.2.4 Estimation of Background Pollutant Concentrations

Options I and II: Background Maps for Estimating Concentrations C(i) for Loading Value Equations - A series of maps have been developed indicating general levels of background pollutant concentrations throughout the United States. These maps are based upon data collected at surface water quality stations comprising the National Hydrologic Bench-Mark Network established by the U.S. Geological Survey. These iso-pollutant maps are presented in Section 12.4 along with a descrption of the National Hydrologic Bench-Mark Network. The background pollutants considered are presented in Table 12-3.

Options III and IV: Use of Local Information for Estimation of Background Pollutant Concentrations - If local information is believed to reflect a better definition of background than the maps presented in Section 12.4, it should be used in the loading value Eqs. (12-1) and (12-2).

12.2.5 Procedure for Using Loading Value Eqs. (12-1) or (12-2)

1. Identify pollutant.

2. Determine area to be considered.

3. Choose units of volume flow to use in equations, i.e., liters per second (cfs) or centimeters per year (in/year).

4. Choose method of estimating pollutant concentration, i.e., background maps or local information.

5. Decisions at Steps 3 or 4 establish option for estimation. When option is established, use Tables 12-1 or 12-2 as appropriate to identify correct value of "a", the conversion factor to obtain proper units of load.

Table 12-2. CONVERSION FACTORS "a" TO BE USED FOR OPTIONS II AND IV LOADING VALUE EQUATION: FLOW AS STREAMFLOW, Q(str)

Constituent	Concentration units	Units of flow "Q(str)"	Value of "a"	Units of load
All except those below	ppm	ℓ/sec	0.0864	kg/day
		cfs	5.39	lb/day
Heavy metals	ppb	ℓ/sec	8.64×10^{-5}	kg/day
		cfs	5.39×10^{-3}	lb/day
Radioactivity	picocuries/ℓ	ℓ/sec	8.64×10^{-4}	picocuries/day
		cfs	2.45×10^{-6}	picocuries/day
Coliforms	MPN/100 ml	ℓ/sec	8.64×10^{-5}	MPN/day
		cfs	2.45×10^{-7}	MPN/day

Table 12-3. LISTING OF BACKGROUND ISOPOLLUTANT MAPS

Constituent	STORET code	Figure No. (see Section 12.4)
Suspended sediment	80154	12-2
Nitrate	00630	12-3
Total phosphorus	00650	12-4
BOD	00310	12-5
Total coliform	31501	12-6
Conductivity	00095	12-7
pH	00400	12-8
Total dissolved solids	00515	12-9
Alkalinity	00410	12-10
Hardness	00900	12-11
Chloride	00940	12-12
Sulfate	00945	12-13
Total heavy metals	Σ Heavy metal parameters	12-14
Iron and manganese	01045 + 01055	12-15
Arsenic, copper, lead, and zinc	01002 + 01042 + 01551 + 01092	12-16
Miscellaneous heavy metals	Σ Remaining heavy metals	12-17
Total radioactivity	01515 + 01516 + 03515 + 03516	12-18
Alpha radioactivity	01515 + 01516	12-19
Beta radioactivity	03515 + 03516	12-20

6. Steps 2 through 6 will yield all necessary inputs for loading values Eqs. (12-1) and (12-2).

7. Compute background loads, Y(i) , for pollutant identified in Step 1.

12.2.6 Examples of Using Loading Value Equations

The following are examples of loading value estimations using Option I. Options II, III, and IV are used in the identical manner, except for input data units.

1. Case I: Background phosphate emisssions from 4,040 ha (10,000 acres) of wheat in western North Dakota

$a = 2.7 \times 10^{-4}$ (6.2×10^{-4}).

Area = 4,040 ha (10,000 acres).

Phosphate concentration (Figure 12-4) = 0.15 ppm.

Average annual runoff = 1.3 cm (0.5 in.).

Load (metric): $0.15 \times 1.3 \times 0.00027 \times 4{,}040$ ha = 0.21 kg/day = 210 g/day.

Load (English): $0.15 \times 0.5 \times 0.00062 \times 10{,}000$ acres = 0.46 lb/day.

2. Case II: Background heavy metals from Spokane River Basin above Roosevelt Lake (Water Resources Council subbasin 1603)

$a = 2.7 \times 10^{-7}$ (6.2×10^{-7}).

Area = 6,404 sq mile = 1,670,000 ha (4,100,000 acres).

Heavy metal concentration (Figure 12-14) = 300 ppb.

Average annual runoff = 25 cm (10 in.).

Load (metric): $300 \times 25 \times 2.7 \times 10^{-7} \times 1{,}670{,}000$ ha = 3.4×10^{3} kg/day = 3.4 MT/day.

Load (English): $300 \times 10 \times 6.2 \times 10^{-7} \times 4{,}100{,}000$ = 7,600 lb/day = 3.8 tons/day.

3. Case III: Background radioactivity emissions from the Cheyenne River Basin (Water Resources Council subbasin 1072):

a = 270 (280).

Area = 20,497 sq miles = 5,300,000 ha (13,000,000 acres).

Radioactivity level (Figure 12-18) = 20 picocuries/liter.

Average annual runoff = 2.5 cm (1.0 in.).

Load (metric): 20 x 2.5 x 270 x 5,300,000 = 7.2 x 10^{10} picocuries/day = 7.2 x 10^4 microcuries/day = 0.072 curies/day.

Load (English): 20 x 1.0 x 280 x 13,000,000 = 7.2 x 10^{10} picocuries/day = 7.2 x 10^4 microcuries/day = 0.072 curies/day.

12.2.7 Estimated Ranges of Accuracy for Stream to Source Options for Background Pollutant Loads

Typical background pollutant loads have been estimated on an annual basis for the background pollutants identified in Table 12-3. As has been stated earlier, the accuracy of these loads is dependent upon the size of the area being considered. Thus, the probable range of values will vary depending upon the size of the area to which the estimation methods are applied.

Table 12-4 through 12-6 present typical loads together with probable ranges of values for the background pollutant loads. Table 12-4 represents small areas (less than 10,000 ha) of county or watershed size. Table 12-5 is concerned with the 10,000 to 10,000,000 ha size, representing an areal range between county and minor river basin. Table 12-6 deals with areas greater than 10,000,000 ha representing minor river basins and larger areas.

As can be seen in the probable ranges of Table 12-4, the use of iso-pollutant maps for the small areas leads to a fairly broad range of accuracy. Local data, where available, will lead to much more accurate loads for areas of county level or smaller. The user is encouraged to use local data for small areas, and consider the iso-pollutant maps as a back-up or reference method.

Table 12-4. EXPECTED ACCURACY OF BACKGROUND POLLUTANT LOADS CALCULATED USING STREAM TO SOURCE METHODS (Area Considered - 100,000 ha (400 sq miles) or Less)

Pollutant	Calculated load (kg/ha/year)	Probable range of loads using iso-pollutant maps: Options I and II (kg/ha/year)	Probable range of loads using local data: Options III and IV (kg/ha/year)
Sediment	250	100 - 1,000	200 - 400
Nitrate	0.5	0.1 - 3	0.3 - 1
Phosphorus	0.1	0.01 - 1	0.07 - 0.3
BOD	2	0.5 - 12	1.5 - 5
Total coliform	1 x 10^{10} a/	10^{6} - 10^{15} a/	10^{8} - 10^{12} a/
TDS	500	100 - 2,000	400 - 600
Alkalinity	200	50 - 500	150 - 300
Hardness	250	100 - 1,000	200 - 300
Chloride	10	1 - 50	8 - 12
Sulfate	250	100 - 1,000	200 - 300
Total heavy metals	1	0.1 - 5	0.5 - 2
Fe + Mn	0.5	0.1 - 3	0.3 - 1.0
As + Cu + Pb + Zn	0.1	0.01 - 0.8	0.05 - 0.2
Miscellaneous heavy metals	0.05	0.001 - 0.5	0.03 - 0.2
Total radioactivity	25 b/	10 - 40 b/	20 - 30 b/
Alpha radioactivity	5 b/	1 - 20 b/	3 - 8 b/
Beta radioactivity	10 b/	3 - 30 b/	7 - 15 b/

---

a/ Load units of MPN/ha/year.

b/ Load units of microcuries/ha/year.

Table 12-5. EXPECTED ACCURACY OF BACKGROUND POLLUTANT LOADS CALCULATED USING STREAM TO SOURCE METHODS (Area Considered - 10,000 to 10,000,000 ha (400 to 40,000 sq miles)

Pollutant	Calculated load (kg/ha/year)	Probable range of loads using iso-pollutant maps: Options I and III (kg/ha/year)	Probable range of loads using local data: Options III and IV (kg/ha/year)
Sediment	250	150 - 1,000	180 - 800
Nitrate	0.5	0.2 - 2	0.2 - 2
Phosphorus	0.1	0.02 - 0.5	0.04 - 0.5
BOD	2	1 - 10	1 - 8
Total coliform	1 x 10^{10}[a]	10^7 - 10^{13}[a]	10^7 - 10^{13}[a]
TDS	500	200 - 1,000	300 - 700
Alkalinity	200	100 - 500	100 - 500
Hardness	250	150 - 500	150 - 500
Chloride	10	3 - 20	5 - 15
Sulfate	250	150 - 500	150 - 500
Total heavy metals	1	0.5 - 3	0.3 - 3
Fe + Mn	0.5	0.2 - 2	0.2 - 2
As + Cu + Pb + Zn	0.1	0.02 - 0.5	0.03 - 0.3
Miscellaneous heavy metals	0.05	0.005 - 0.3	0.01 - 0.5
Total radioactivity	25[b]	18 - 35[b]	18 - 35[b]
Alpha radioactivity	5[b]	2 - 10[b]	2 - 10[b]
Beta radioactivity	10[b]	5 - 25[b]	5 - 25[b]

---

[a] Load units of MPN/ha/year.

[b] Load units of microcuries/ha/year.

Table 12-6. EXPECTED ACCURACY OF BACKGROUND POLLUTANT LOADS CALCULATED USING STREAM TO SOURCE METHODS (Area Considered - 10,000,000 ha (40,000 sq miles) or Greater)

Pollutant	Calculated load (kg/ha/year)	Probable range of loads using iso-pollutant maps: Options I and II (kg/ha/year)	Probable range of loads using local data: Options III and IV (kg/ha/year)
Sediment	250	200 - 500	100 - 1,000
Nitrate	0.5	0.3 - 1.0	0.1 - 3
Phosphorus	0.1	0.05 - 0.3	0.02 - 1.0
BOD	2	1 - 5	0.5 - 12
Total coliform	1 x 10^{10}[a]	10^8 - 10^{12}[a]	10^6 - 10^{15}[a]
TDS	500	400 - 800	100 - 1,000
Alkalinity	200	150 - 300	100 - 1,000
Hardness	250	200 - 400	100 - 1,000
Chloride	10	8 - 15	3 - 20
Sulfate	250	200 - 300	100 - 1,000
Total heavy metals	1	0.8 - 2	0.1 - 5
Fe + Mn	0.5	0.3 - 1.5	0.1 - 3
As + Cu + Pb + Zn	0.1	0.05 - 0.3	0.01 - 1.0
Miscellaneous heavy metals	0.05	0.01 - 0.2	0.001 - 0.5
Total radioactivity	25[b]	20 - 30[b]	10 - 40[b]
Alpha radioactivity	5[b]	3 - 8[b]	1 - 20[b]
Beta radioactivity	10[b]	8 - 15[b]	3 - 30[b]

---

[a] Load units of MPN/ha/year.

[b] Load units of microcuries/ha/year.

Background pollutant loads and their probable ranges for areas varying in size from a county (10,000 ha) to a minor river basin (10,000,000 ha) are shown in Table 12-5. In these intermediate sized areas, the difference in accuracy between the use of the iso-pollutant maps and local data is judged to be relatively small. Thus, either method should result in satisfactory estimation of background loads. It is recommended, however, that the user should lean towards the local data if he is considering the low range of the areal spread indicated in Table 12-5.

For larger areas, the use of iso-pollutant maps will yield satisfactory results. The uncertainty represented by Table 12-6 is no greater than the differences between contours on the iso-pollutant maps. On the other hand, if local data are extrapolated to large areas, a significant amount of error can be introduced into the calculations. In principle, background pollutant loadings for large areas could be obtained by summing many smaller areas for which background loadings have been obtained using local data. It is questionable, however, whether this summing procedure would be any more accurate than the use of Option I and II methods using the iso-pollutant maps for the large areas.

12.3 SOURCE TO STREAM OPTION

12.3.1 Description of Source to Stream Option

The source to stream approach for estimating pollutant loads from background involves using the Universal Soil Loss Equation and its associated delivery ratio factor to estimate soil losses from land having natural cover. These "natural" areas include grassland, rangeland, desert, forest, or woodlands, and areas transitional between forest-grassland etc. A table of cover C factors are presented to facilitate the identification of the proper cover factor to be used. These C values are presented in Table 12-7 and 12-8. Background sediment loads should be estimated using the methods outlined in Section 3.0, together with the appropriate C factor. Regional vegetative cover patterns needed to identify specific C values in Table 12-7 and 12-8 can be established using descriptors of natural vegetation such as that presented in the U.S. Geological Survey's National Atlas, Plates 90 and 91 (potential natural vegetation).

This method can also be used for estimating pollutant loads transmitted by sediment attachment, e.g., nitrogen and phosphorus. In this case, one would substitute the Y(S) value for background into the appropriate loading functions described in Section 4.0. Heavy metals in the sediment can be estimated using procedures in Section 8.5.

Table 12-7. "C" VALUES FOR PERMANENT PASTURE, RANGELAND, AND IDLE LAND[1]

Vegetal canopy Type and height of raised canopy[b] column no.:	Canopy cover[c] (%) 2	Type[d] 3	Cover that contacts the surface Percent ground cover[a]					
			0 4	20 5	40 6	60 7	80 8	95-100 9
No appreciable canopy		G	0.45	0.20	0.10	0.042	0.013	0.003
		W	0.45	0.24	0.15	0.090	0.043	0.011
Canopy of tall weeds or short brush (0.5 m fall height)	25	G	0.36	0.17	0.09	0.038	0.012	0.003
		W	0.36	0.20	0.13	0.082	0.041	0.011
	50	G	0.26	0.13	0.07	0.035	0.012	0.003
		W	0.26	0.16	0.11	0.075	0.039	0.011
	75	G	0.17	0.10	0.06	0.031	0.011	0.003
		W	0.17	0.12	0.09	0.067	0.038	0.011
Appreciable brush or bushes (2 m fall height)	25	G	0.40	0.18	0.09	0.040	0.013	0.003
		W	0.40	0.22	0.14	0.085	0.042	0.011
	50	G	0.34	0.16	0.085	0.038	0.012	0.003
		W	0.34	0.19	0.13	0.081	0.041	0.011
	75	G	0.28	0.14	0.08	0.036	0.012	0.003
		W	0.28	0.17	0.12	0.077	0.040	0.011
Trees but no appreciable low brush (4 m fall height)	25	G	0.42	0.19	0.10	0.041	0.013	0.003
		W	0.42	0.23	0.14	0.087	0.042	0.011
	50	G	0.39	0.18	0.09	0.040	0.013	0.003
		W	0.39	0.21	0.14	0.085	0.042	0.011
	75	G	0.36	0.17	0.09	0.039	0.012	0.003
		W	0.36	0.20	0.13	0.083	0.041	0.011

---

[a] All values shown assume: (1) random distribution of mulch or vegetation, and (2) mulch of appreciable depth where it exists.

[b] Average fall height of waterdrops from canopy to soil surface: m = meters.

[c] Portion of total-area surface that would be hidden from view by canopy in a vertical projection (a bird's-eye view).

[d] G: Cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 5 cm (2 in.) deep.

W: Cover at surface is mostly broadleaf herbaceous plants (as weeds) with little lateral-root network near the surface, and/or undecayed residue.

Table 12-8. "C" FACTORS FOR WOODLAND[1]

Stand condition	Tree canopy percent of area[a]	Forest litter percent of area[b]	Undergrowth[c]	"C" factor
Well stocked	100-75	100-90	Managed[d]	0.001
			Unmanaged[d]	0.003-0.011
Medium stocked	70-40	85-75	Managed	0.002-0.004
			Unmanaged	0.01-0.04
Poorly stocked	35-20	70-40	Managed	0.003-0.009
			Unmanaged	0.02-0.09[e]

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[a] When tree canopy is less than 20%, the area will be considered as grassland, or cropland for estimating soil loss. See Table 13-1.

[b] Forest litter is assumed to be at least 2 in. deep over the percent ground surface area covered.

[c] Undergrowth is defined as shrubs, weeds, grasses, vines, etc., on the surface area not protected by forest litter. Usually found under canopy openings.

[d] Managed - grazing and fires are controlled.
Unmanaged - stands that are overgrazed or subjected to repeated burning.

[e] For unmanaged woodland with litter cover of less than 75%, C values should be derived by taking 0.7 of the appropriate values in Table 13-1. The factor of 0.7 adjusts for the much higher soil organic matter on permanent woodland.

12.3.2 Estimated Ranges of Accuracy for the Stream to Source (USLE-Sediment) Option for Background Pollutant Loads

Background pollutant loads for several sediment related pollutants are presented in Table 12-9, together with their probable ranges. The probable ranges can be translated as a percentage range based on the calculated load, e.g., the range for a calculated total phosphorus load of 1.5 kg/ha/year would be 0.3 to 15 kg/ha/year.

Table 12-9. EXPECTED ACCURACY OF BACKGROUND POLLUTANT LOADS CALCULATED USING THE SOURCE TO STREAM (USLE-SEDIMENT) OPTION

Pollutant	Calculated load (kg/ha/year)	Probable range of loads (kg/ha/year)
Sediment	500	100 - 1,000
Total nitrogen	3	0.3 - 10
Total phosphorus	0.5	0.1 - 5
Organic matter	50	5 - 200
BOD	5	0.5 - 20
Heavy metals	5	0.5 - 20

12.4 ISO-POLLUTANT MAPS FOR ESTIMATING BACKGROUND POLLUTANT LOADS

The U.S. Geological Survey established the National Hydrologic Benchmark Network[2/] in order to obtain water quality data for "natural background."

This network consists of 27 surface water stations in 37 dates chosen using the following criteria:

1. No man-made storage, regulation, or diversion currently exists or is probable for many years.

2. Groundwater within the basin will not be affected by pumping from wells.

3. Conditions are favorable for accurate measurement of streamflow, chemical and physical quality of water, groundwater conditions, and the various characteristics of weather, principally precipitation.

4. The probability is small of special natural changes due to such things as major activities of beavers, overgrazing or overbrowsing by game animals, or extensive fires.

The approximate locations of the 57 benchmark stations are mapped in Figure 12-1, and defined more specifically in Table 12-10.

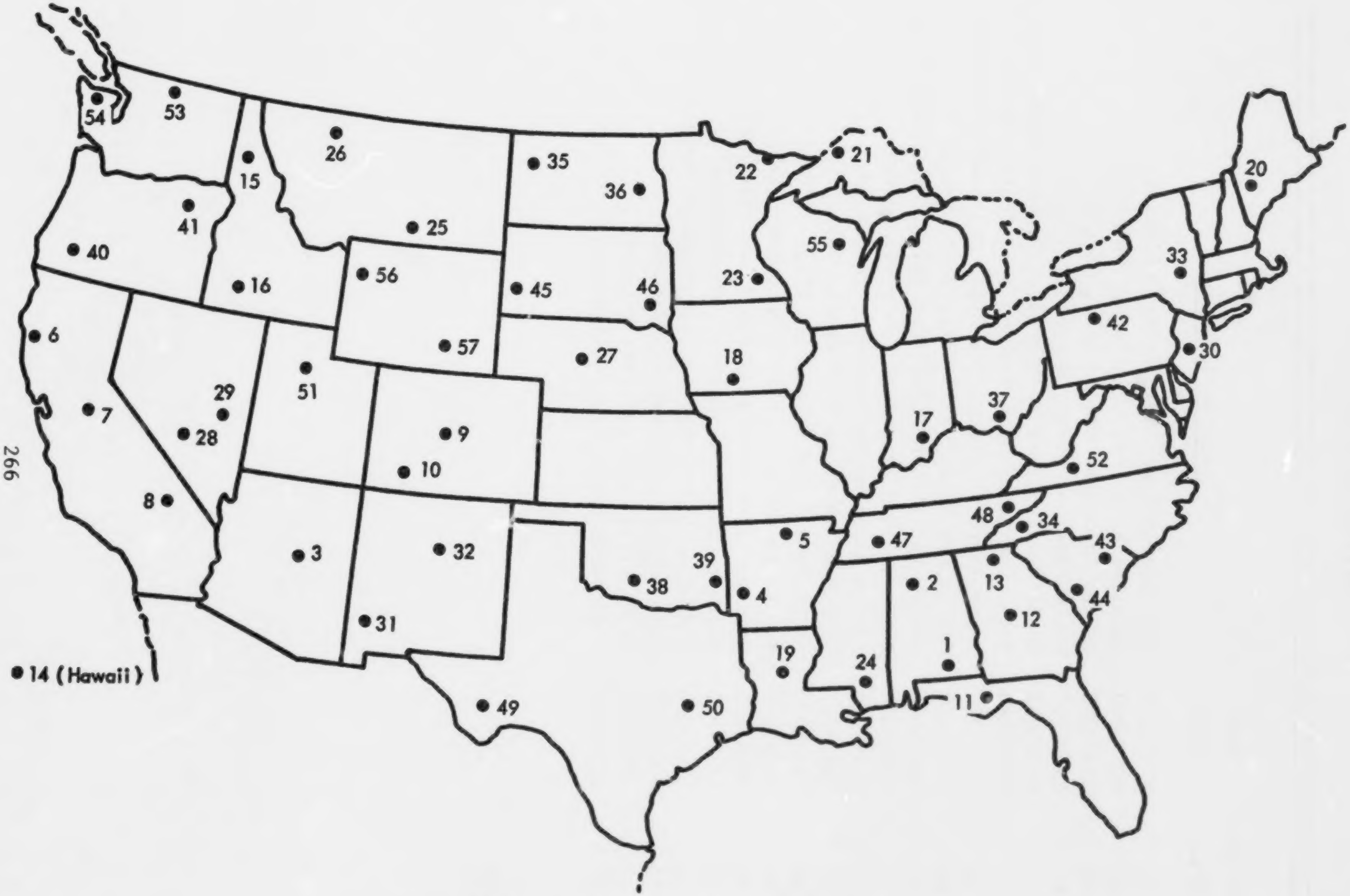
A series of iso-pollutant maps have been developed based upon average concentration ranges obtained at the stations comprising the National Hydrologic Benchmark Network. The maps (Figures 12-2 through 12-20) are for the pollutants identified in Table 12-3.

Table 12-10. LOCATION OF HYDROLOGIC BENCHMARK STATIONS[2/]

Station No.	USGS code	Station location
1	02369800	Blackwater River near Bradley, Alabama
2	02450250	Sipsey Fork near Grayson, Alabama
3	09508300	Wet Bottom Creek near Childs, Arizona
4	07340300	Cossatot River near Vandervoort, Arkansas
5	07060710	North Sylamore Creek near Fifty Six, Arkansas
6	11475560	Elder Creek near Branscomb, California
7	11264500	Merced River near Yosemite, California
8	10250600	Wildrose Creek near Wildrose Station, California
9	07083000	Halfmoon Creek near Malta, Colorado
10	09352900	Vallecito Creek near Bayfield, Colorado
11	02327100	Sopchoppy River near Sopchoppy, Florida
12	02212600	Falling Creek near Juliette, Georgia
13	02178400	Tallulah River near Clayton, Georgia
14	16717000	Honolii Stream near Papaikou, Hawaii
15	12416000	Hayden Creek below North Fork, near Hayden Lake, Idaho
16	13169500	Wickahoney Creek near Bruneau, Idaho
17	03276700	South Hogan Creek near Dillsboro, Indiana
18	06897950	Elk Creek near Decatur City, Iowa
19	07373000	Big Creek at Pollock, Louisiana
20	01054200	Wild River at Gilead, Maine
21	04001000	Washington Creek at Windigo, Isle Royale, Michigan
22	05124480	Kawishiwi River near Ely, Minnisota
23	05376000	North Fork Whitewater River near Elba, Minnisota
24	02479155	Cypress Creek near Janice, Mississippi
25	06288200	Beauvais Creek near St. Xavier, Montana
26	05014500	Swiftcurrent Creek at Many Glacier, Montana
27	06775900	Dismal River near Thedford, Nebraska
28	10249300	South Twin River near Round Mountain, Nevada
29	10244950	Steptoe Creek near Ely, Nevada
30	01466500	McDonalds Branch in Lebanon St. Forest, New Jersey
31	09430600	Mogollon Creek near Cliff, New Mexico
32	08377900	Rio Mora near Tererro, New Mexico
33	01362198	Esopus Creek at Shandaken, New York
34	03460000	Cataloochee Creek near Cataloochee, North Carolina
35	06332515	Bear Den Creek near Mandaree, North Dakota
36	05064900	Beaver Creek near Finley, North Dakota
37	03237280	Upper Twin Creek at McGaw, Ohio

Table 12-10 (Concluded)

Station No.	USGS code	Station location
38	07311200	Blue Beaver Creek near Cache, Oklahoma
39	07335700	Kiamichi River near Big Cedar, Oklahoma
40	11492200	Crater Lake near Crater Lake, Oregon
41	13331500	Minam River at Minam, Oregon
42	01545600	Young Womans Creek near Renovo, Pennsylvania
43	02135300	Scape Ore Swamp near Bishipville, South Carolina
44	02197300	Upper Three Runs near New Ellenton, South Carolina
45	06409000	Castle Creek near Hill City, South Dakota
46	06478540	Little Vermillion River near Salem, South Dakota
47	03604000	Buffalo River near Flat Woods, Tennessee
48	03497300	Little River above Townsend, Tennessee
49	08431700	Limpia Creek above Fort Davis, Texas
50	08103900	South Fork Rocky Creek near Briggs, Texas
51	10172200	Red Butte Creek near Salt Lake City, Utah
52	02038850	Holiday Creek near Andersonville, Virginia
53	12447390	Andrews Creek near Mazama, Washington
54	12039300	N.F. Quinault River near Amanda Park, Washington
55	04063700	Popple River near Fence, Wisconsin
56	13018300	Cache Creek near Jackson, Wyoming
57	06623800	Encampment River near Encampment, Wyoming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47
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43
2
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44
12
31
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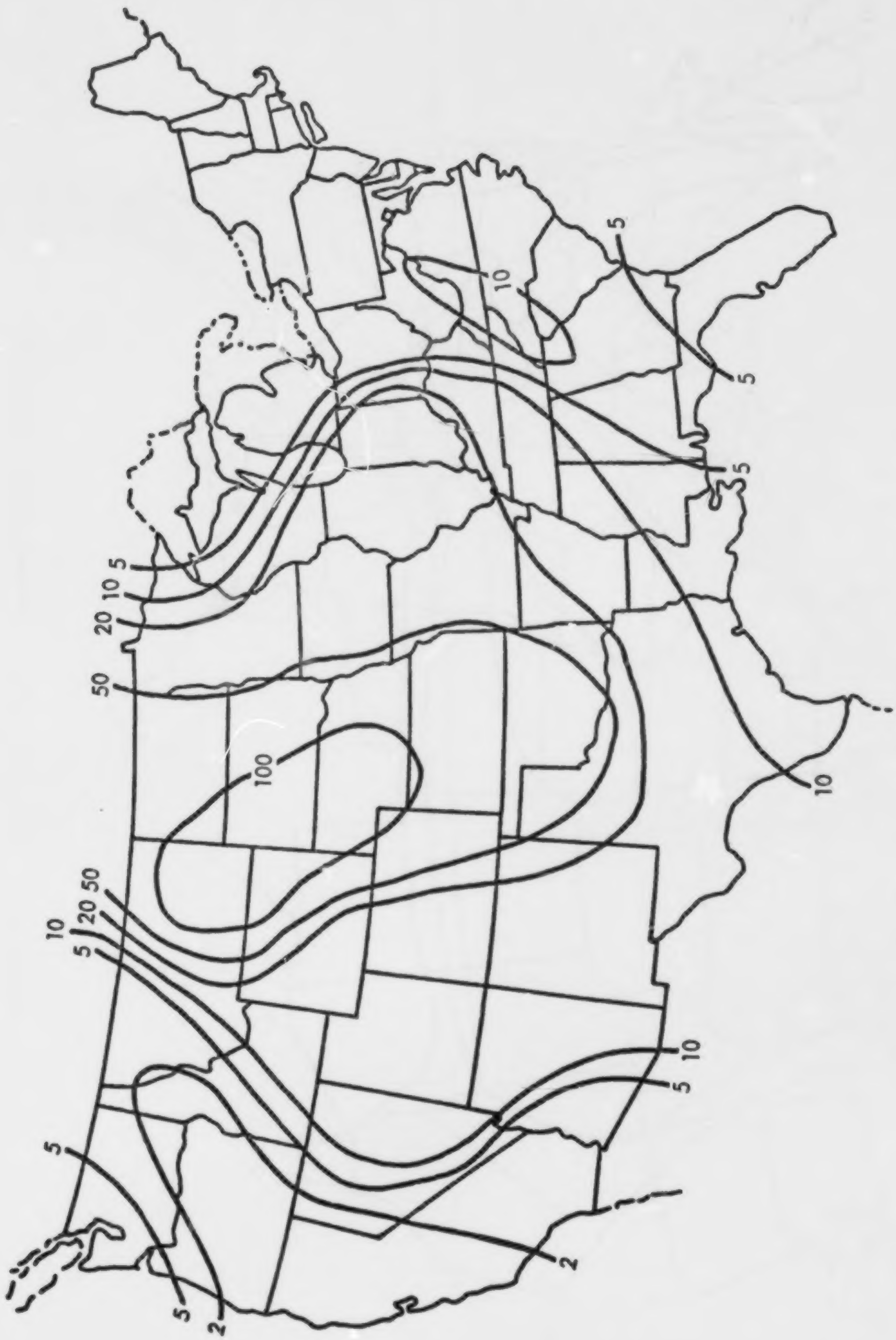
24
1
11
14 (Hawaii)
49
50

Figure 12-1. The National Hydrologic Benchmark Network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100
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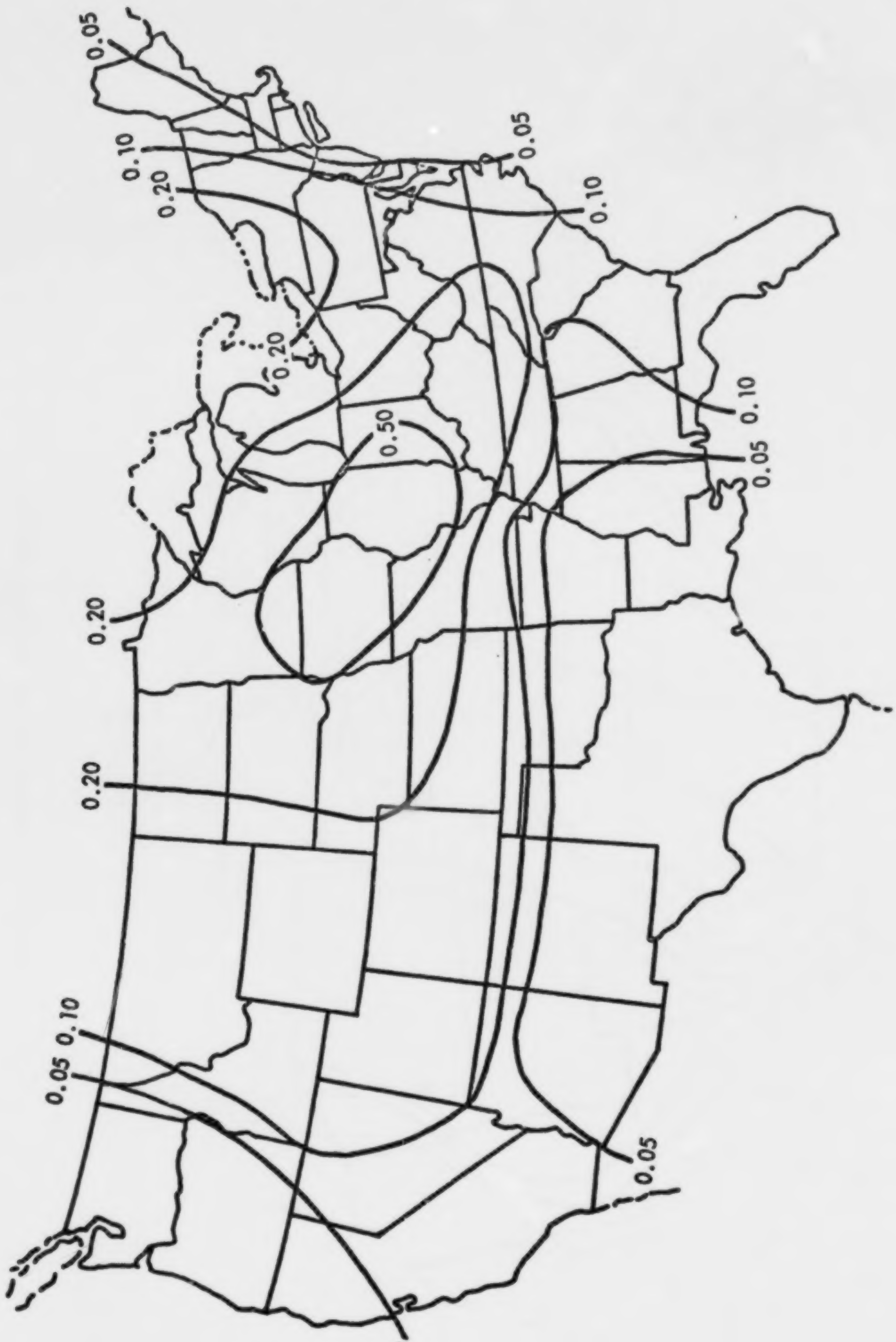
10

Figure 12-2. Background suspended sediment (ppm)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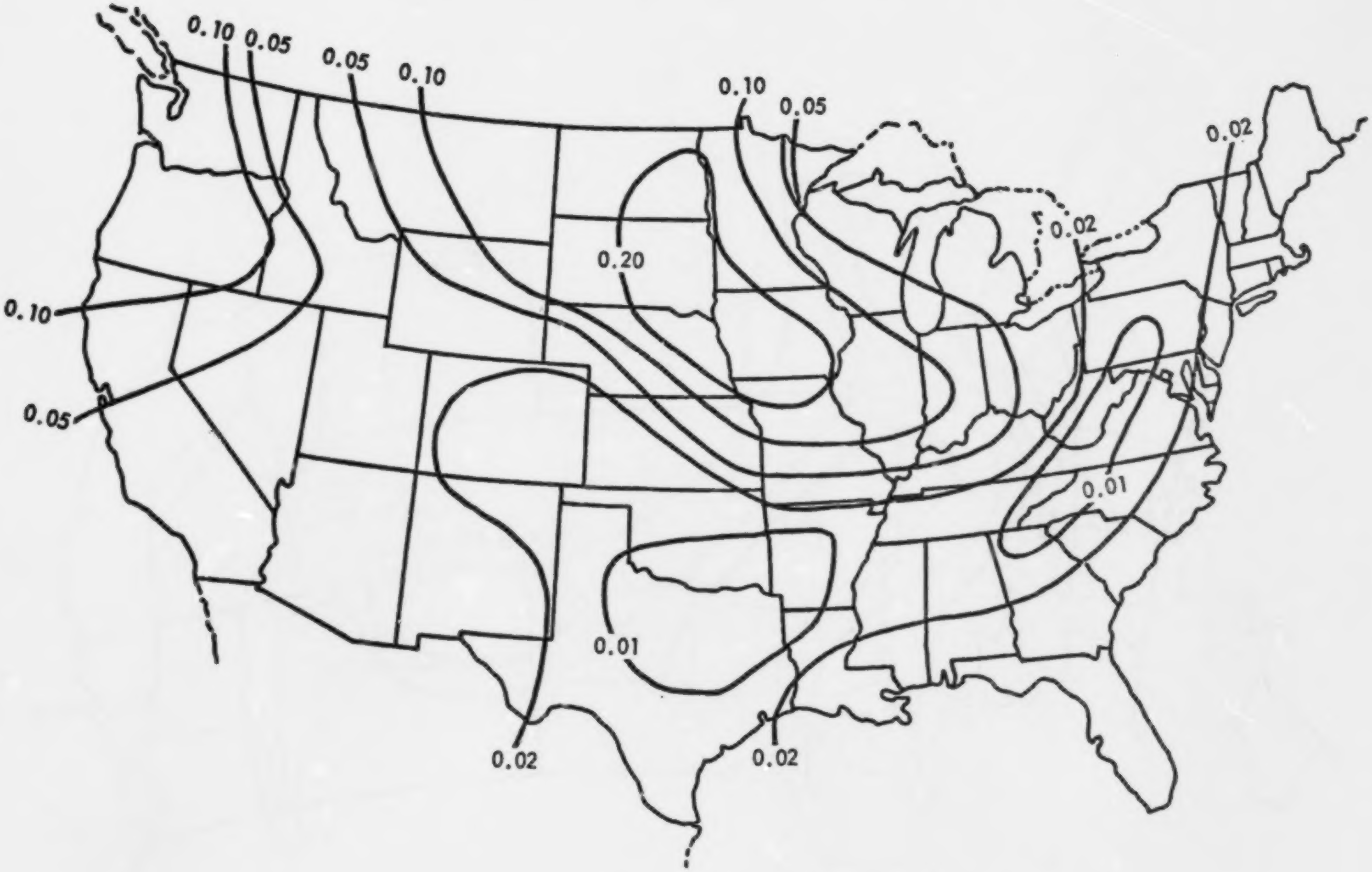
0.10
0.20
0.05
0.10
0.20
0.50
0.10
0.05
0.20
0.20
0.05 0.10
0.05
0.05

Figure 12-3. Background nitrate concentrations (ppm as N)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0.05
0.05
0.10
0.10
0.05
0.02
0.20
0.02
0.10
0.05
0.01
0.01
0.02
0.02

Figure 12-4. Background total phosphorus concentrations (ppm as P)

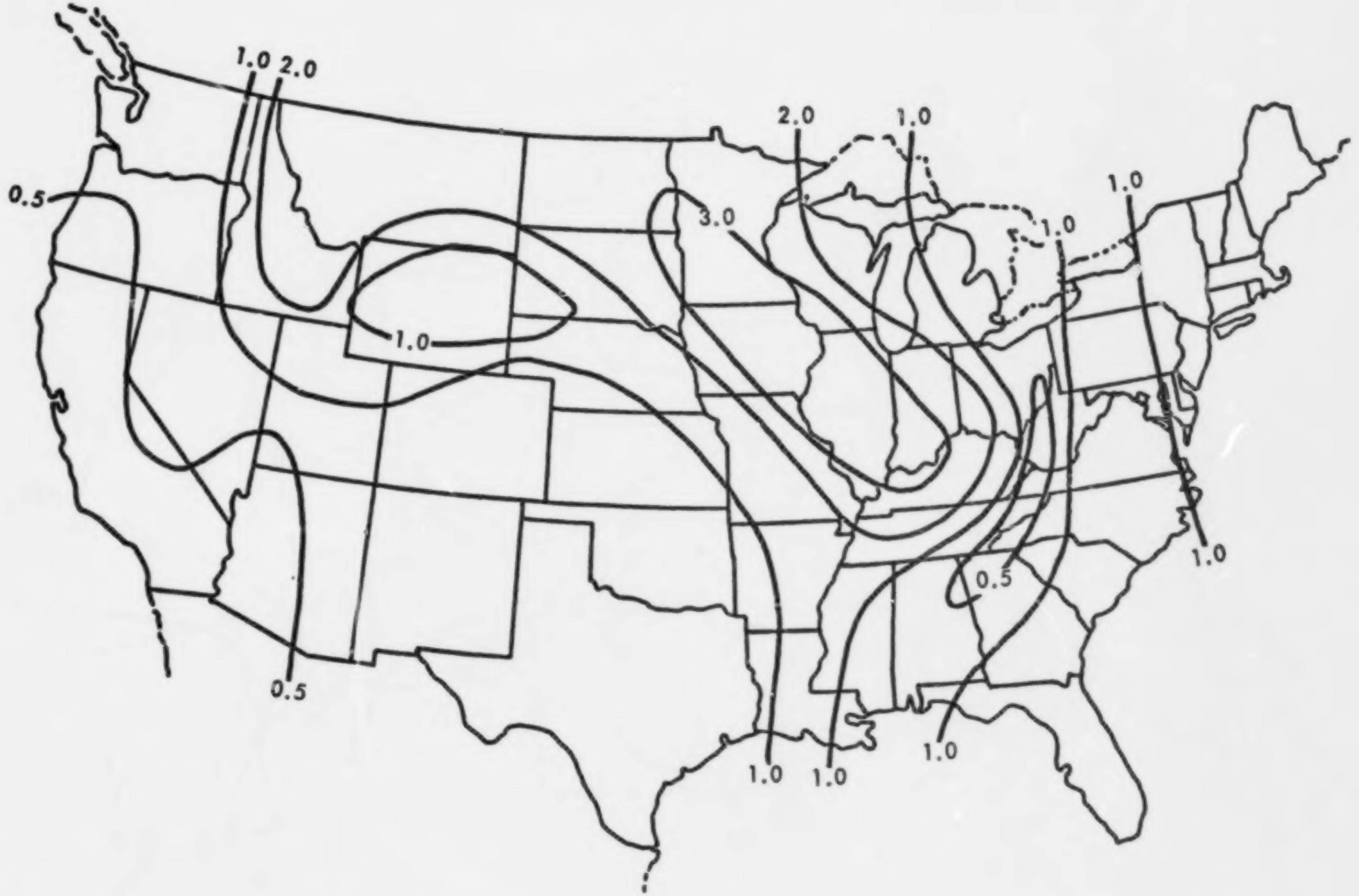

1.0
2.0
0.5
1.0
3.0
2.0
1.0
1.0
1.0
0.5
1.0
0.5
1.0
1.0
1.0

Figure 12-5. Background BOD concentrations (ppm)

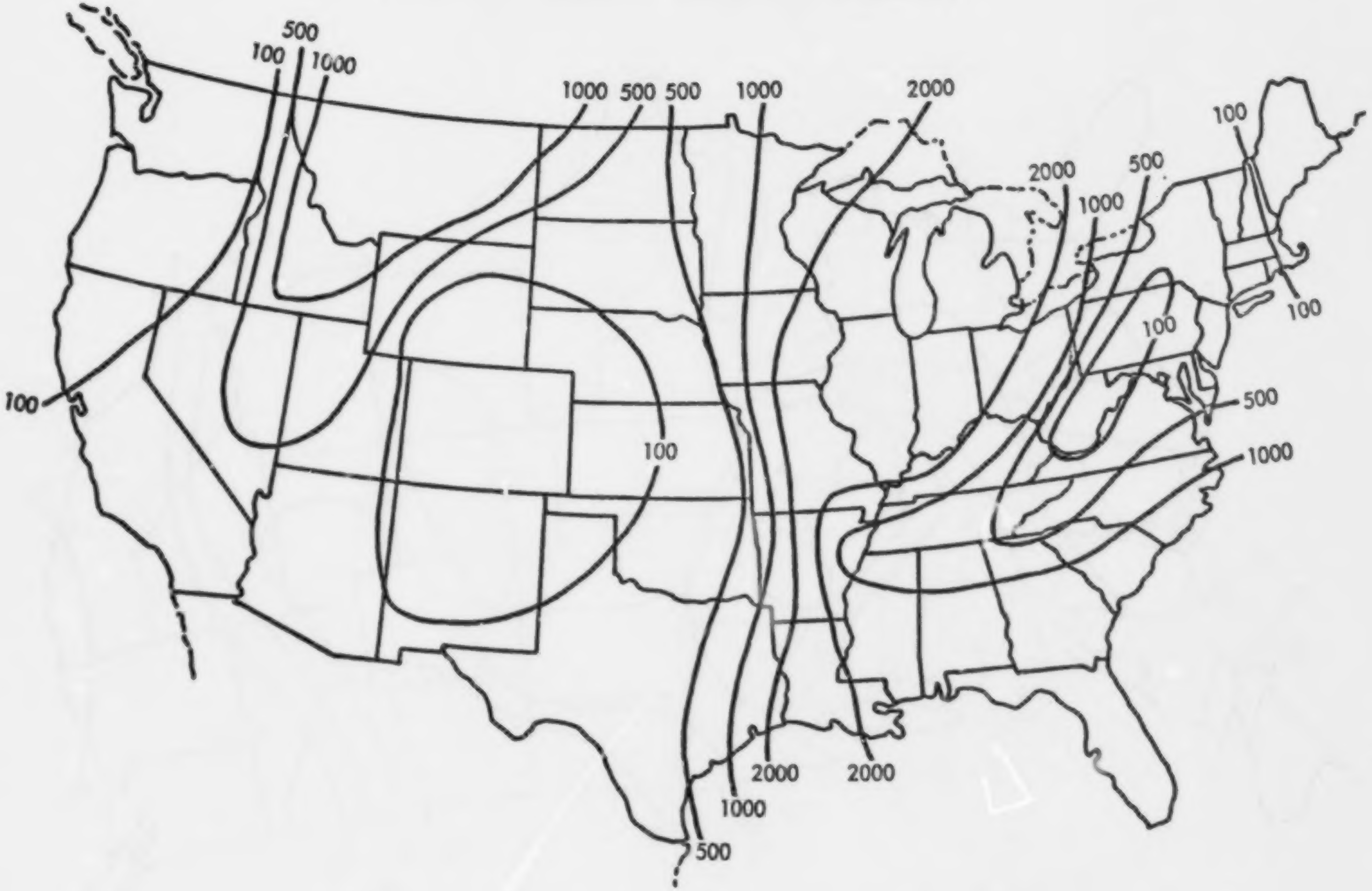
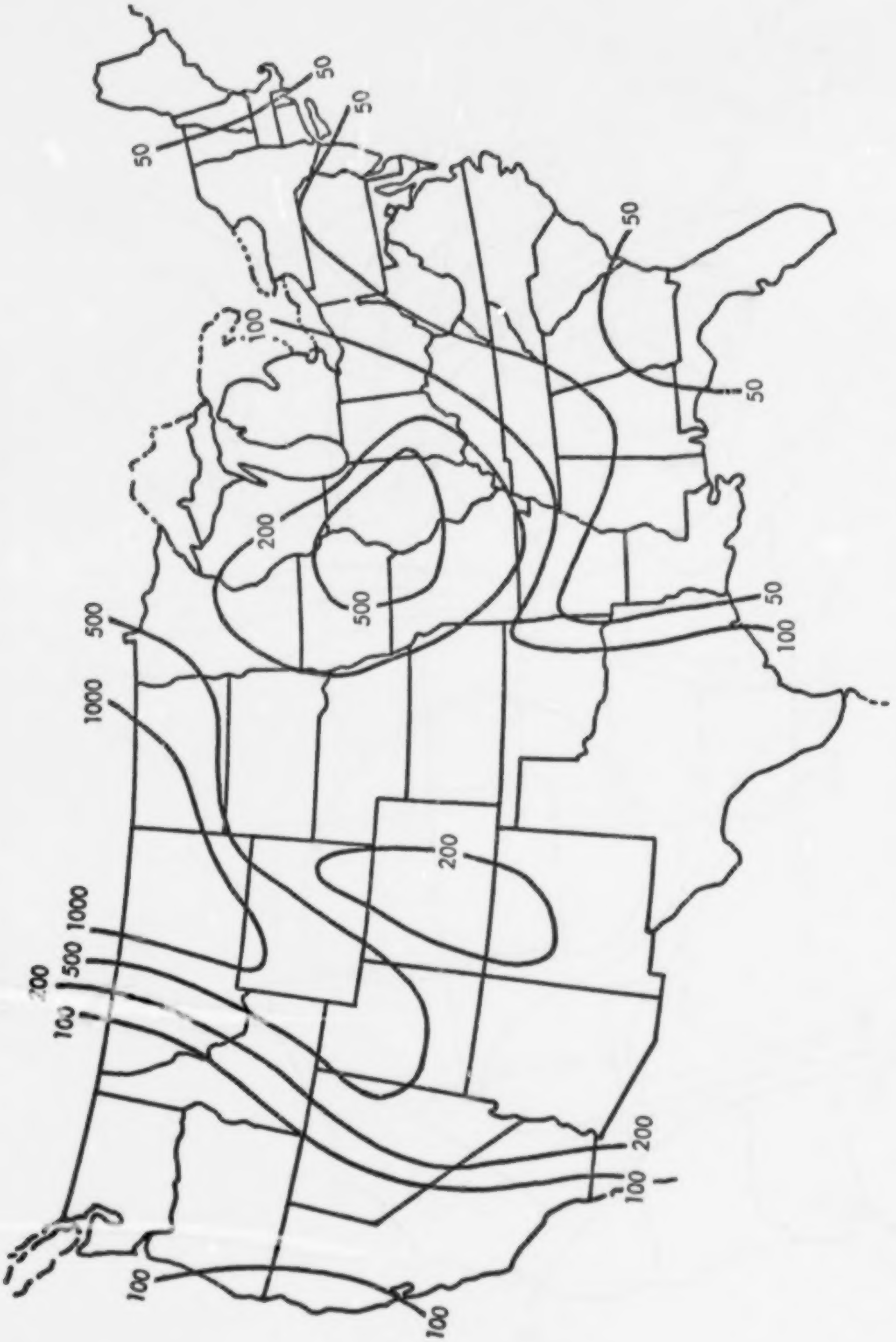

500
100
1000
1000
500
500
1000
2000
100
2000
500
1000
100
100
100
500
100
1000
100
2000
2000
1000
500

Figure 12-6. Background total coliform count (MPN/100 ml)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50
50
50
50
100
50
200
500
500
1000
100
50
200
1000
500
200
100
200
100
100
100

Figure 12-7. Background conductivity (micromhos)

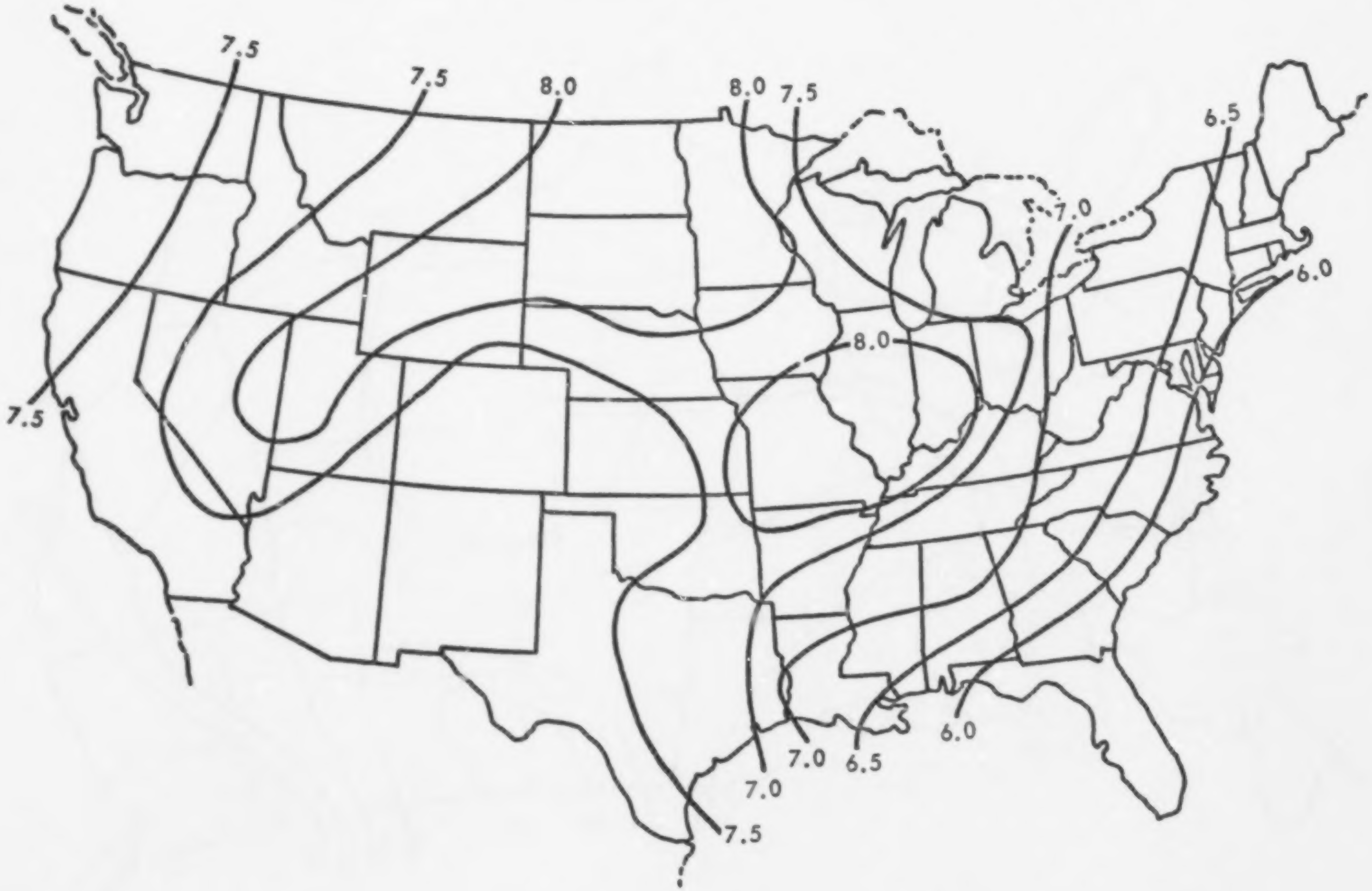

7.5
7.5
8.0
8.0
7.5
6.5
7.0
6.0
8.0
7.5
7.0
7.0
6.5
6.0
7.0
7.5

Figure 12-8. Background pH (standard units)

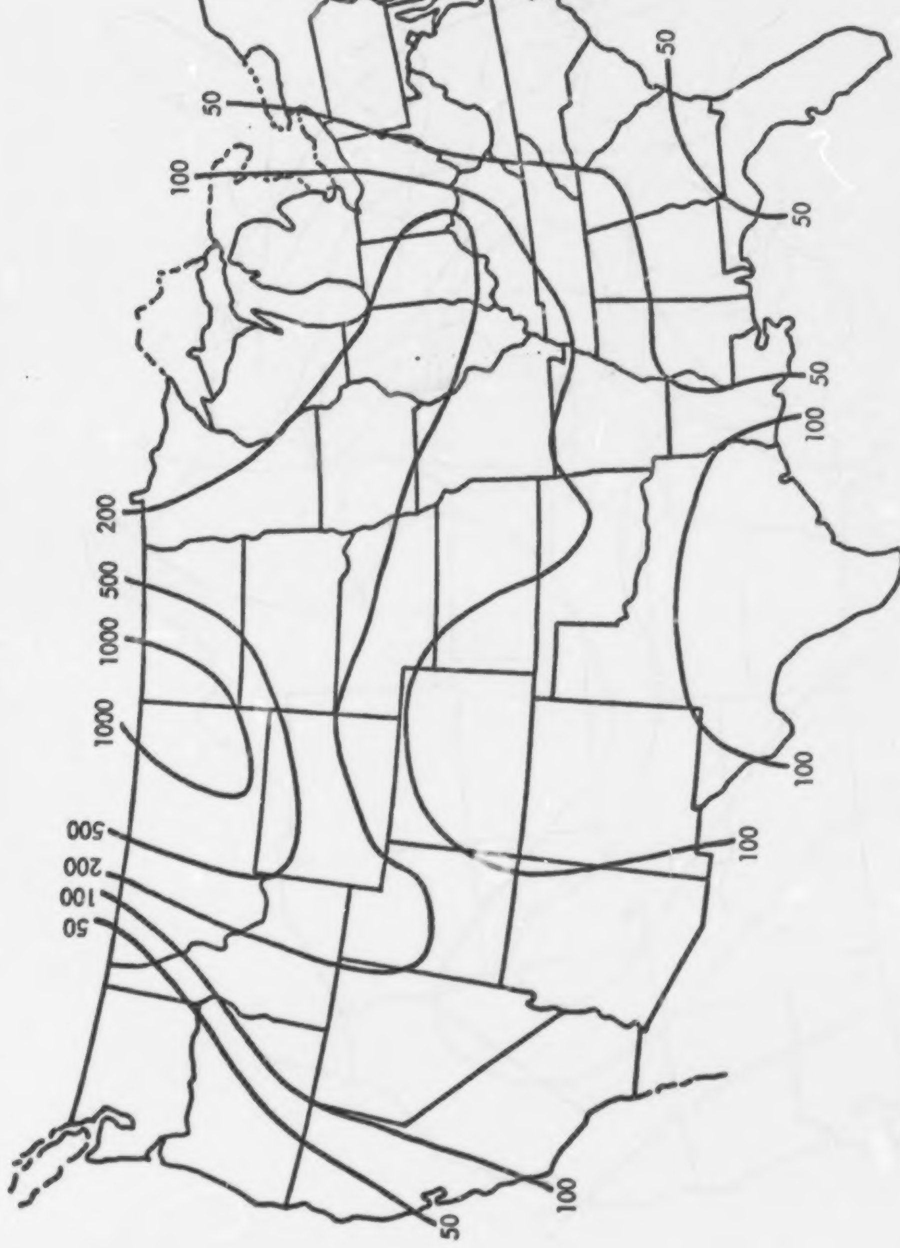

50
100
200
500
1000
1000
500
200
100
50
50
100
50
100
100
100
100
50
50

Figure 12-9. Background total dissolved solids (ppm)

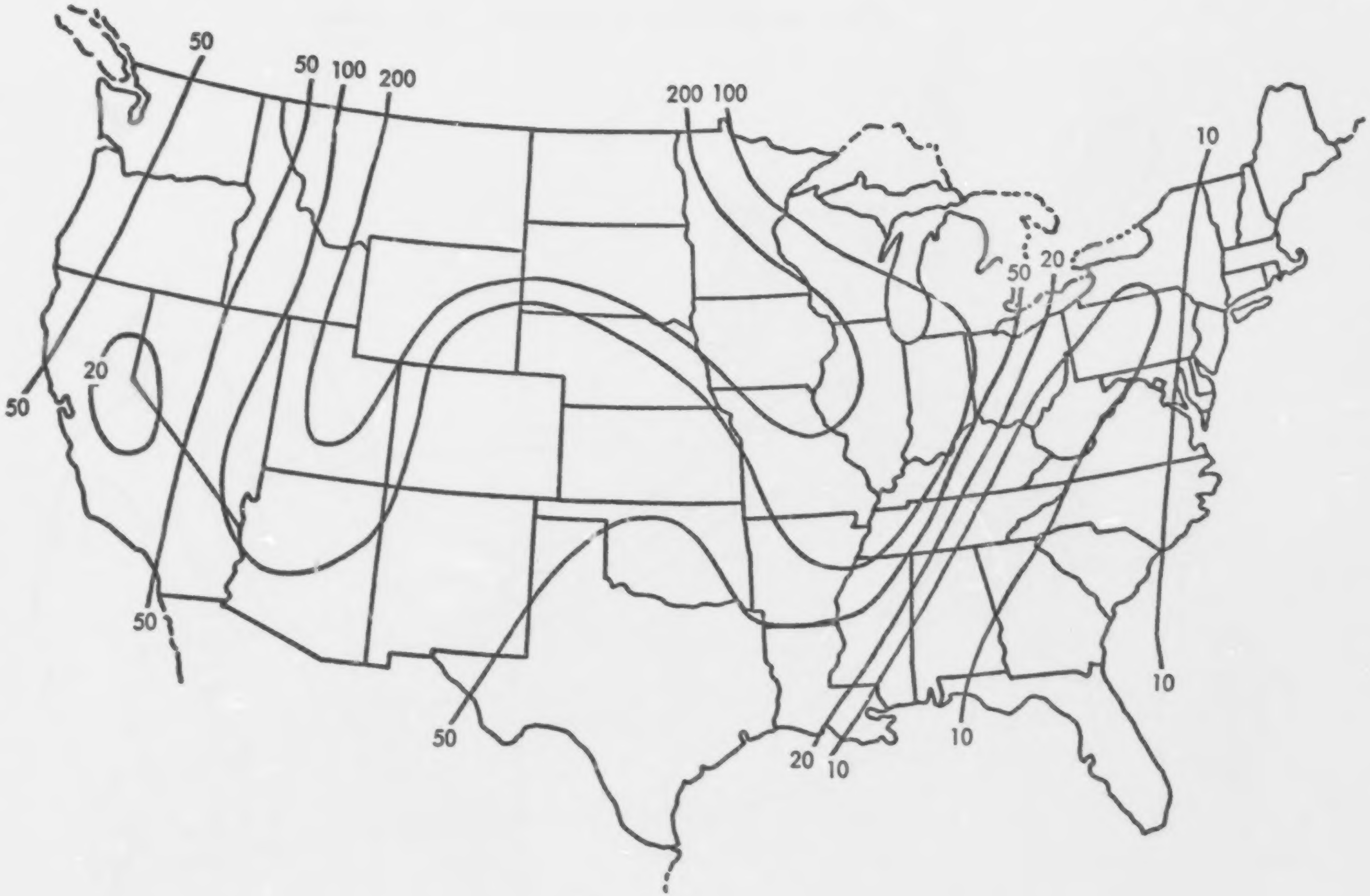

50
50
100
200
200
100
10
50
20
20
50
50
50
20
10
10
10

Figure 12-10. Background alkalinity (ppm $CaCO_3$)

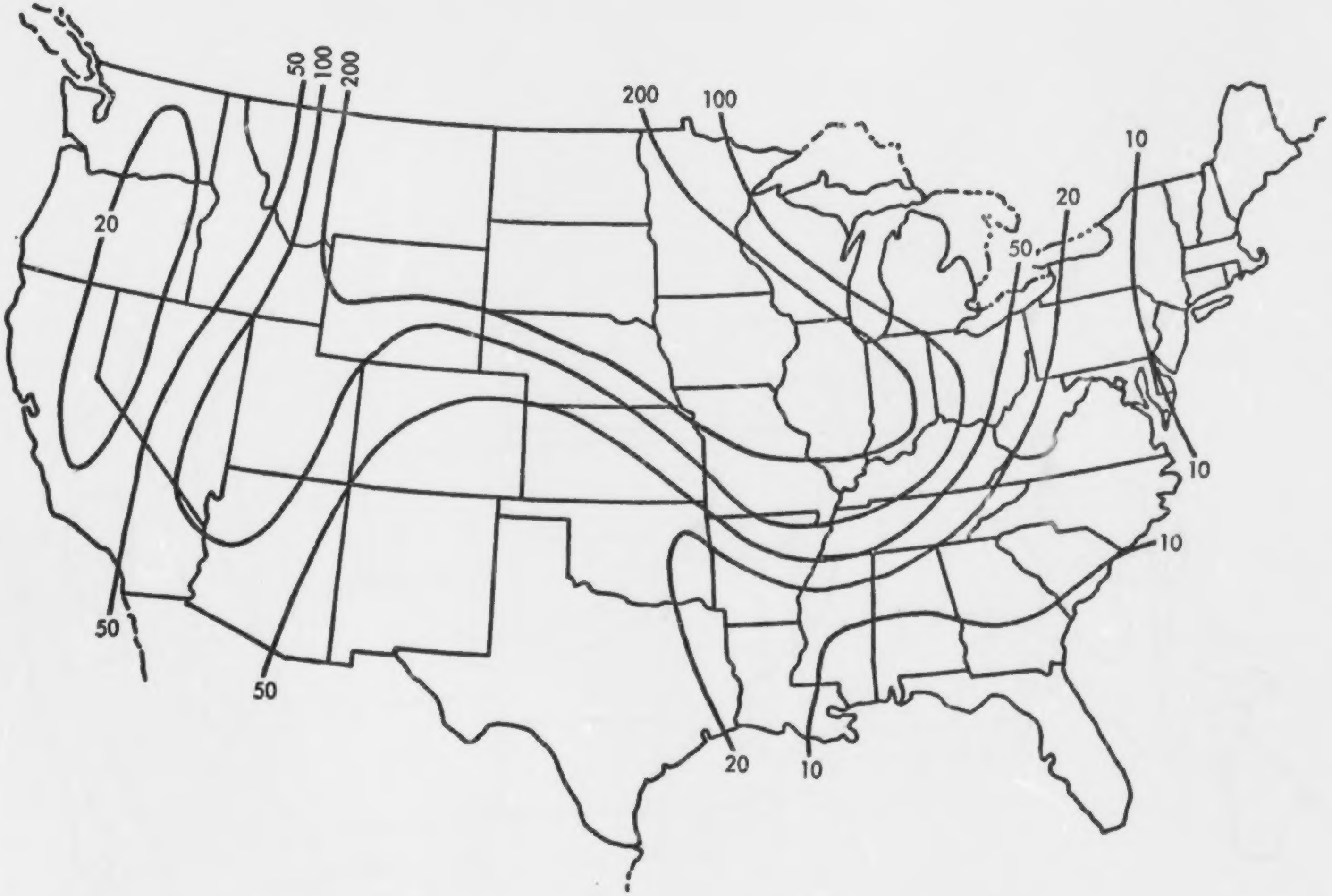

50
100
200
200
100
10
20
50
20
10
10
50
50
20
10

Figure 12-11. Background hardness (ppm as $CaCO_3$)

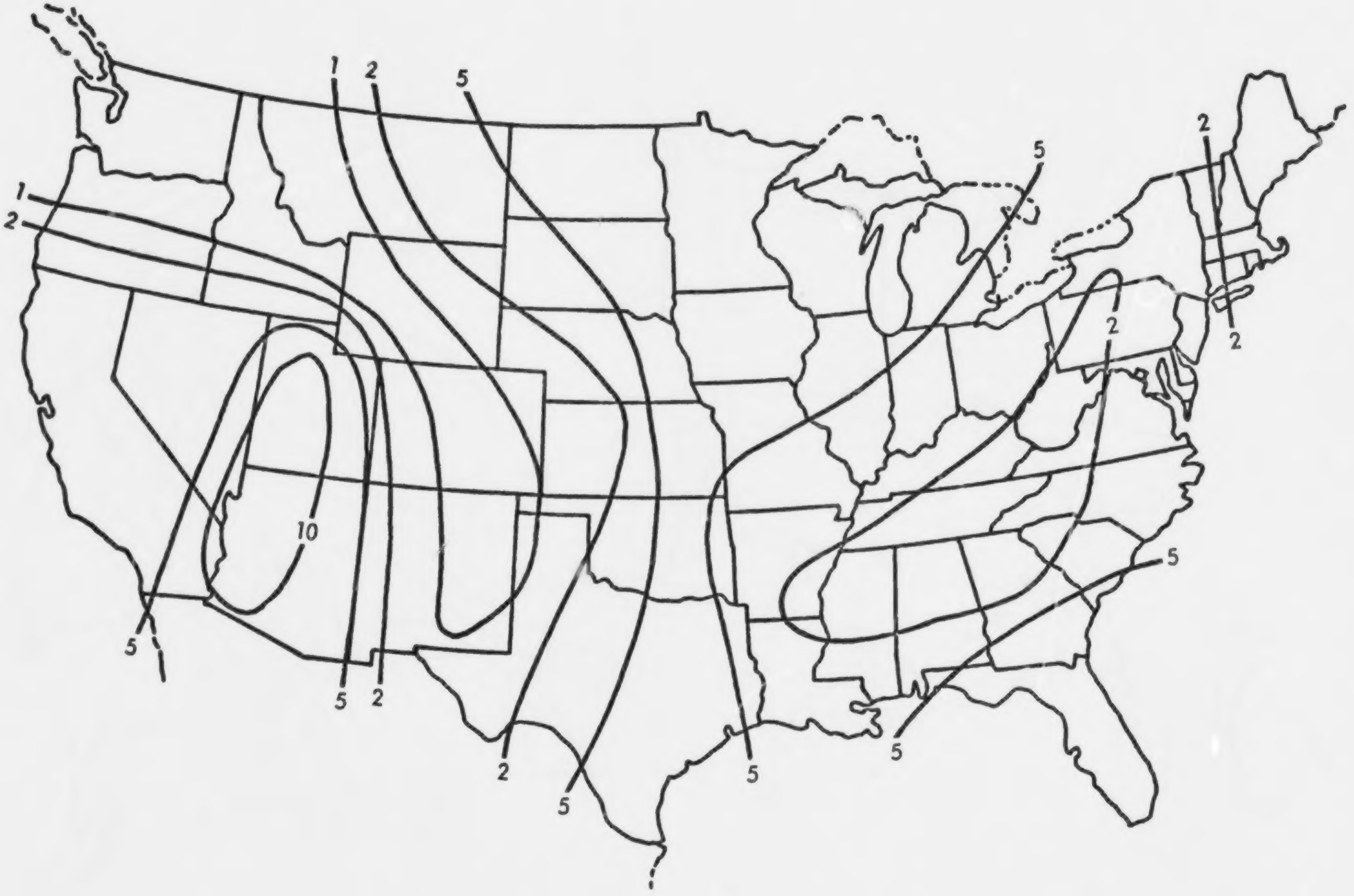

1
2
5
2
5
2
1
2
10
5
2
5
5
2
5
5
2
5
5

Figure 12-12. Background chloride concentrations (ppm)

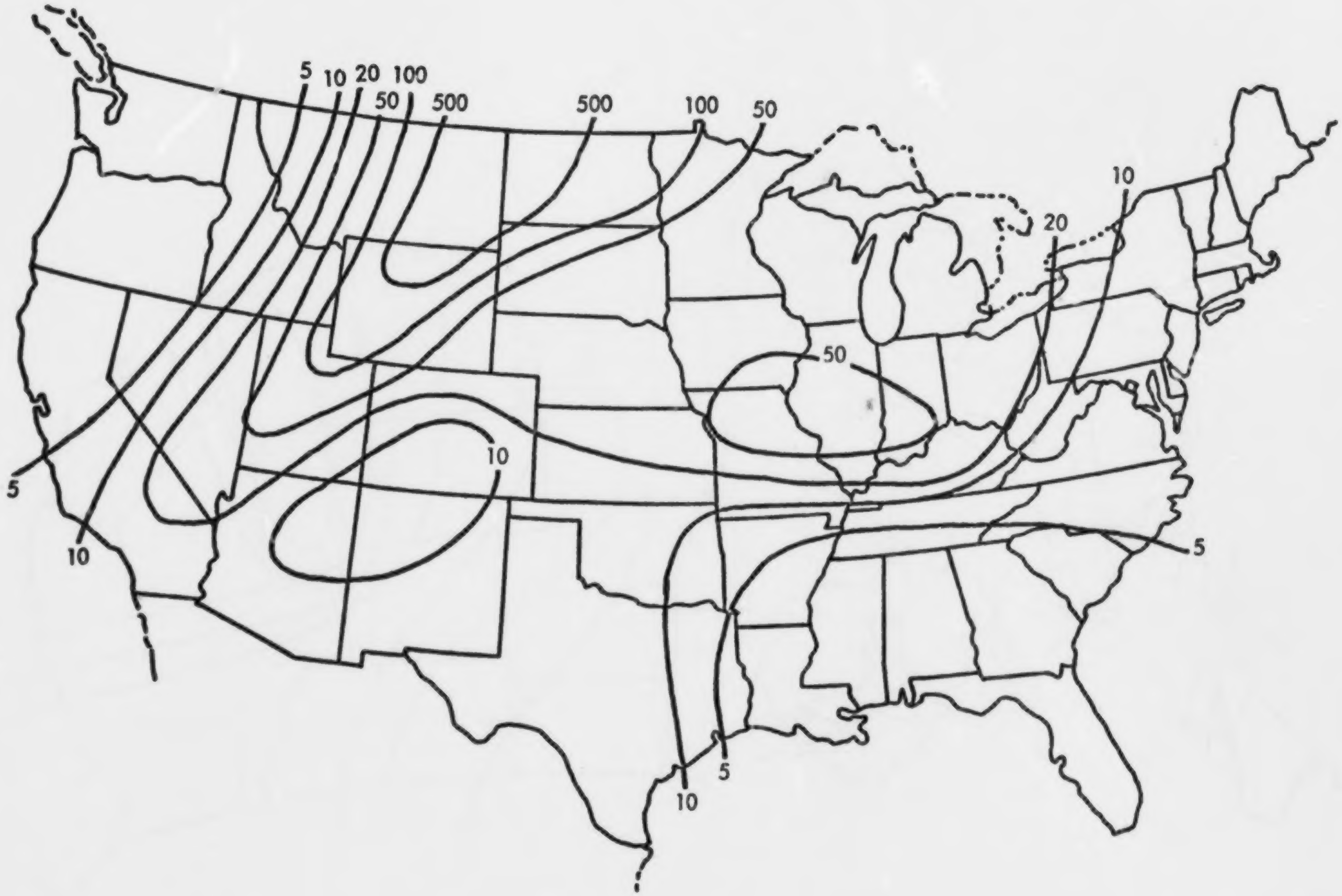

5
10
20
100
50
500
500
100
50
10
20
50
10
5
10
5
10
5

Figure 12-13. Background sulfate concentrations (ppm)

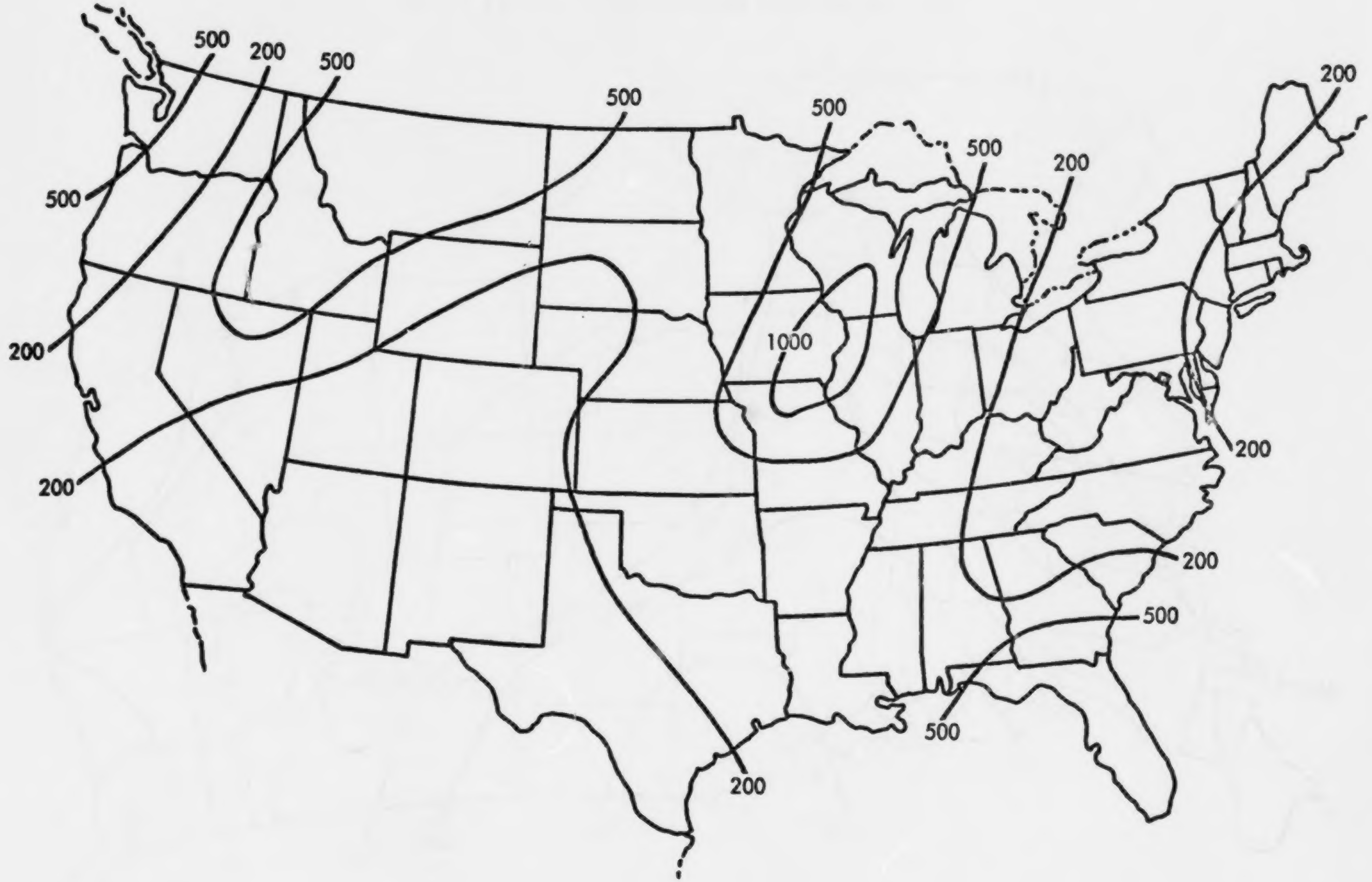

500
200
500
500
500
500
200
200
500
200
200
1000
200
200
500
500
200

Figure 12-14. Background total heavy metal concentrations (ppb)

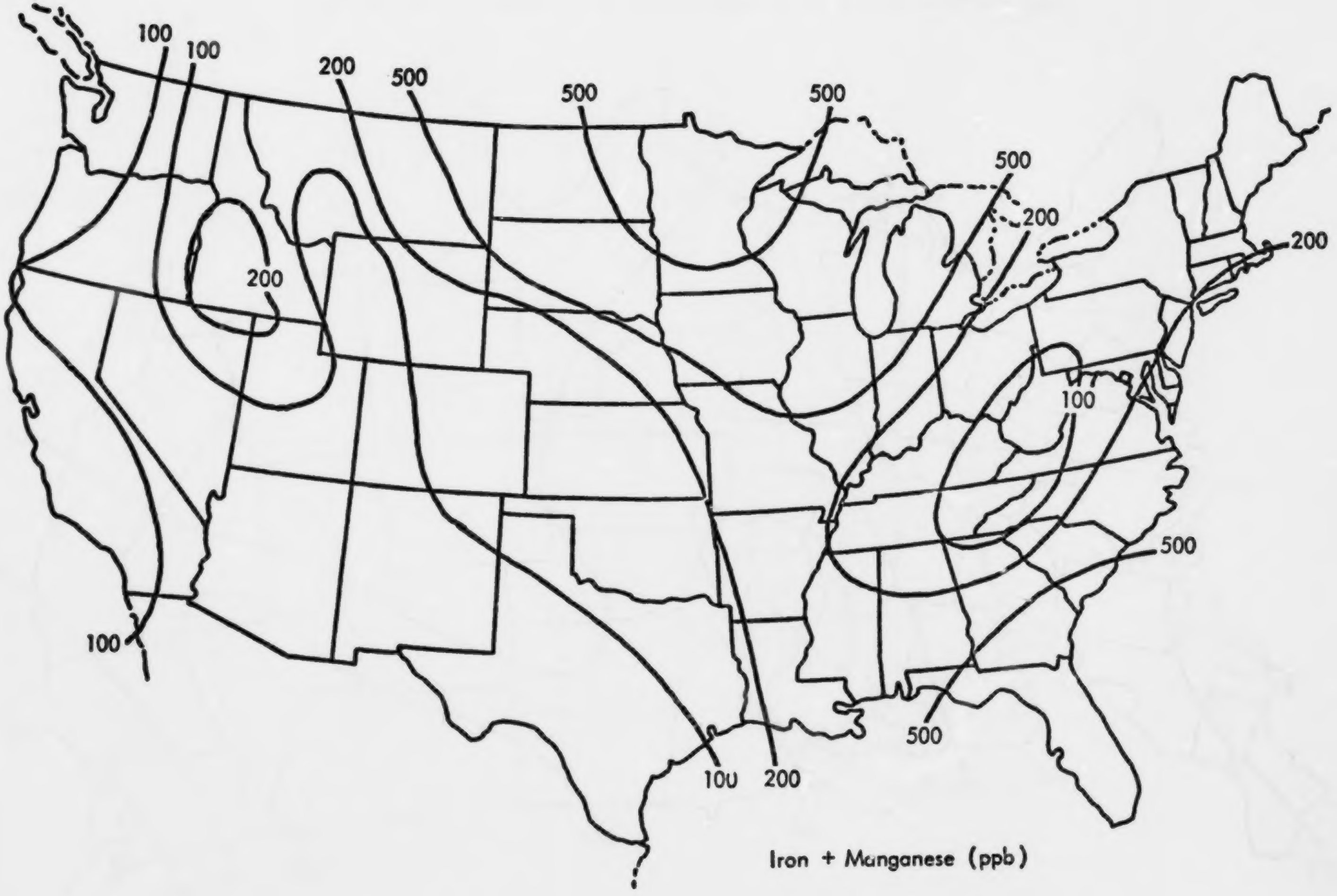

100
100
200
500
500
500
500
200
200
200
100
500
500
100
100
200
Iron + Manganese (ppb)

Figure 12-15. Background iron + manganese (ppb)

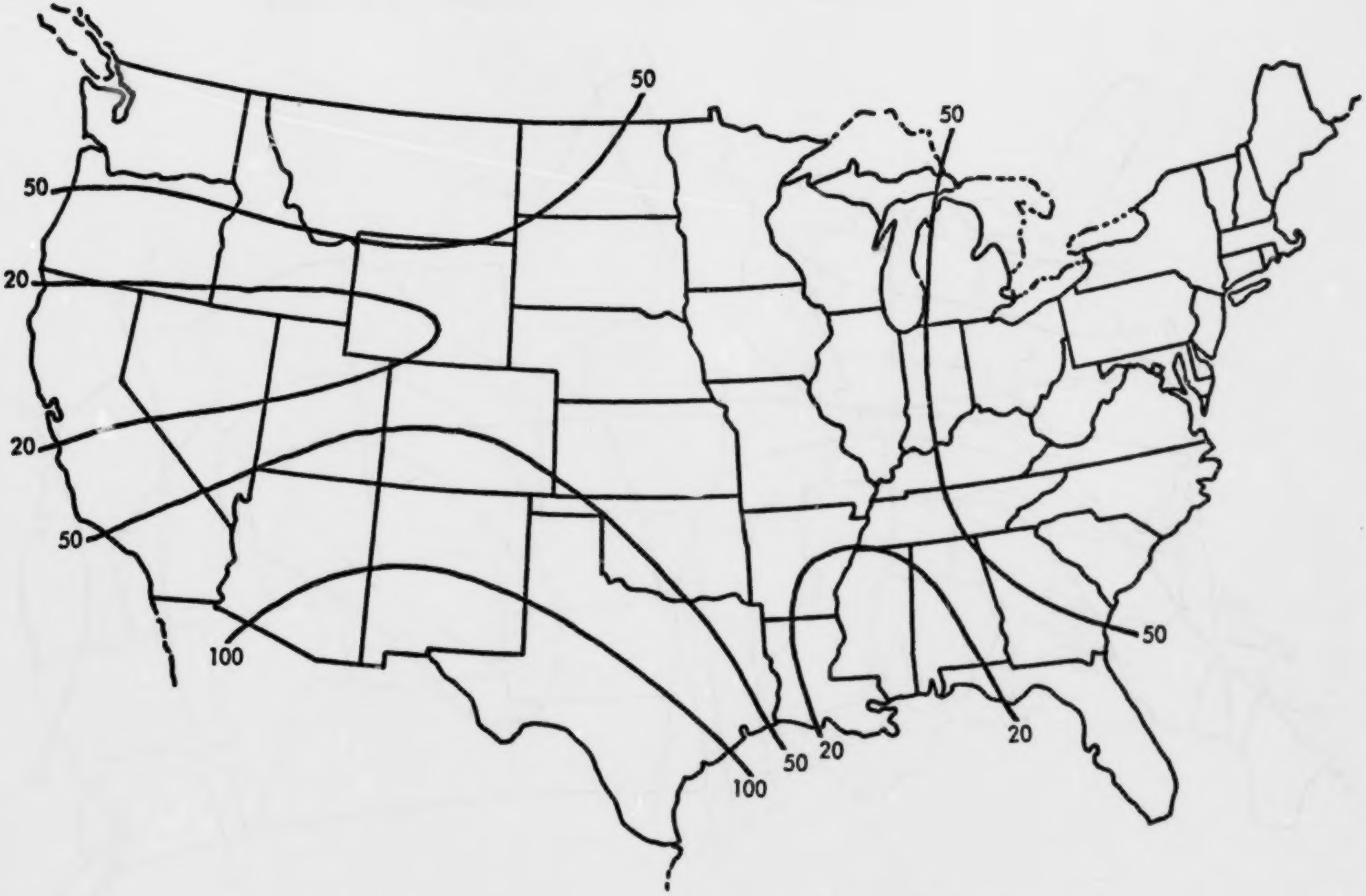

50
50
50
20
20
50
100
100
50
20
20
50

Figure 12-16. Background arsenic + copper + lead + zinc (ppb)

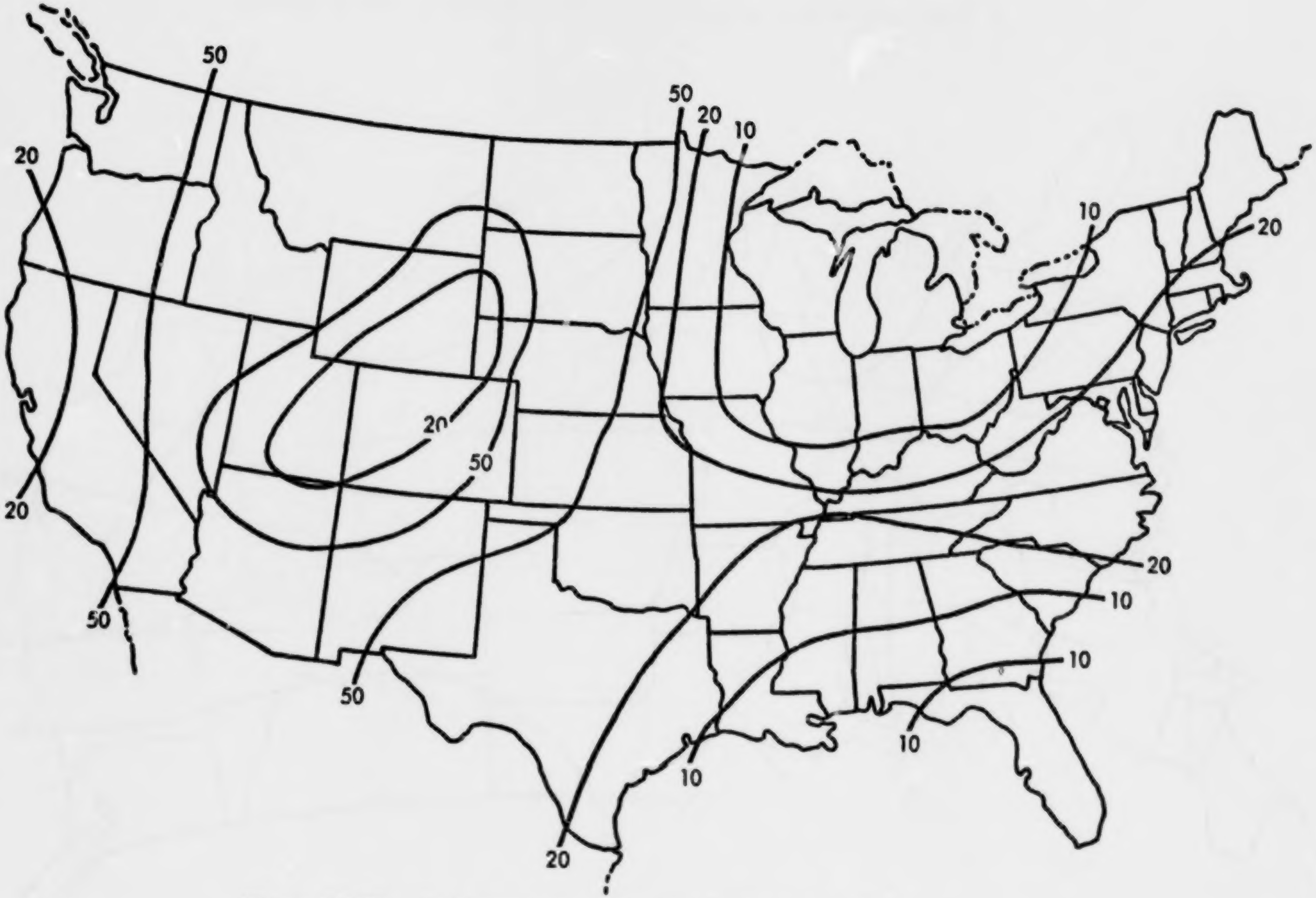

50
20
50
50
20
10
10
20
20
20
50
20
50
50
20
10
10
10
10
20

Figure 12-17. Background miscellaneous heavy metals (ppb)

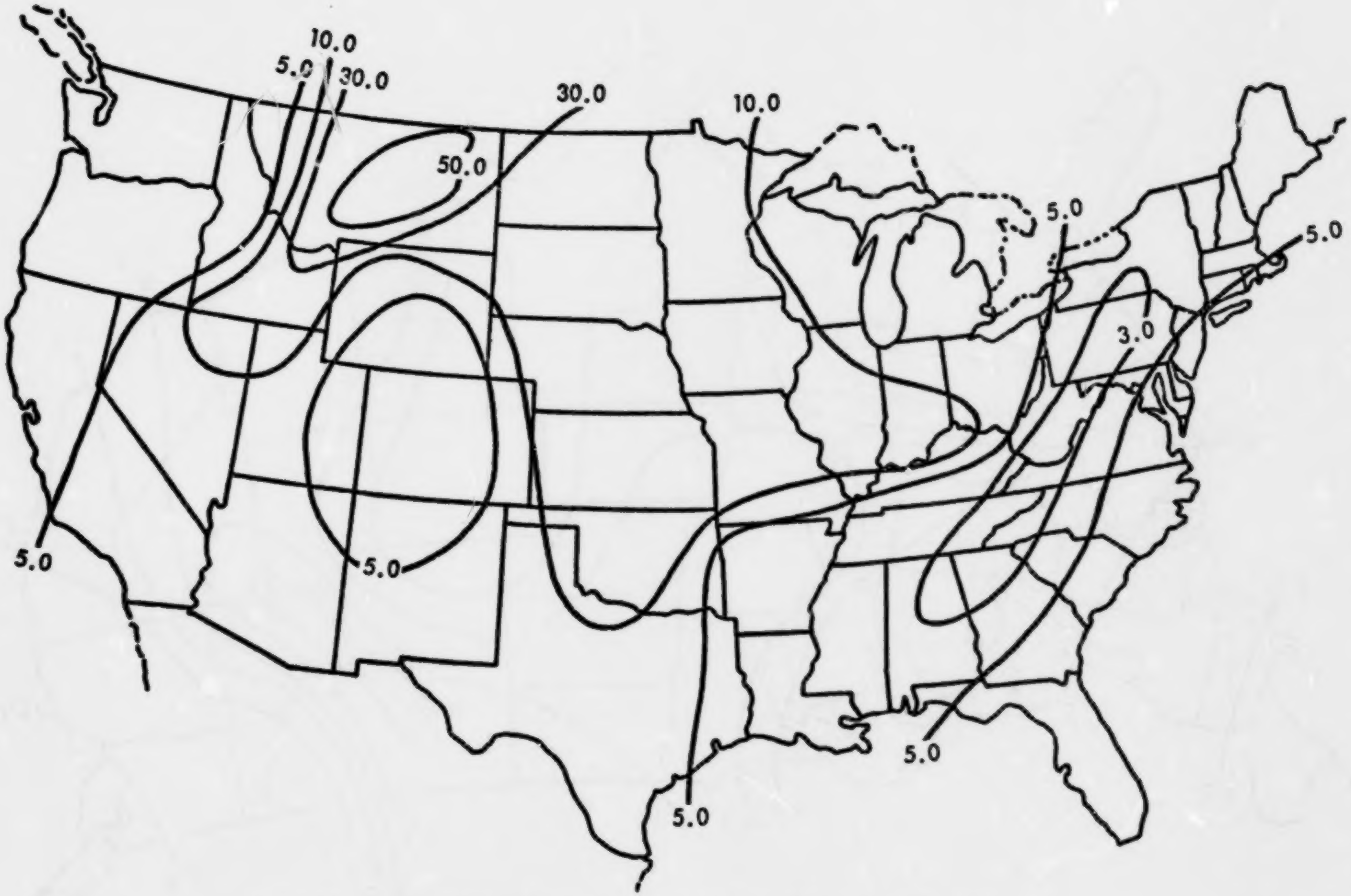

10.0
5.0
30.0
30.0
10.0
50.0
5.0
5.0
3.0
5.0
5.0
5.0
5.0

Figure 12-18. Background total radioactivity (picocuries/liter)

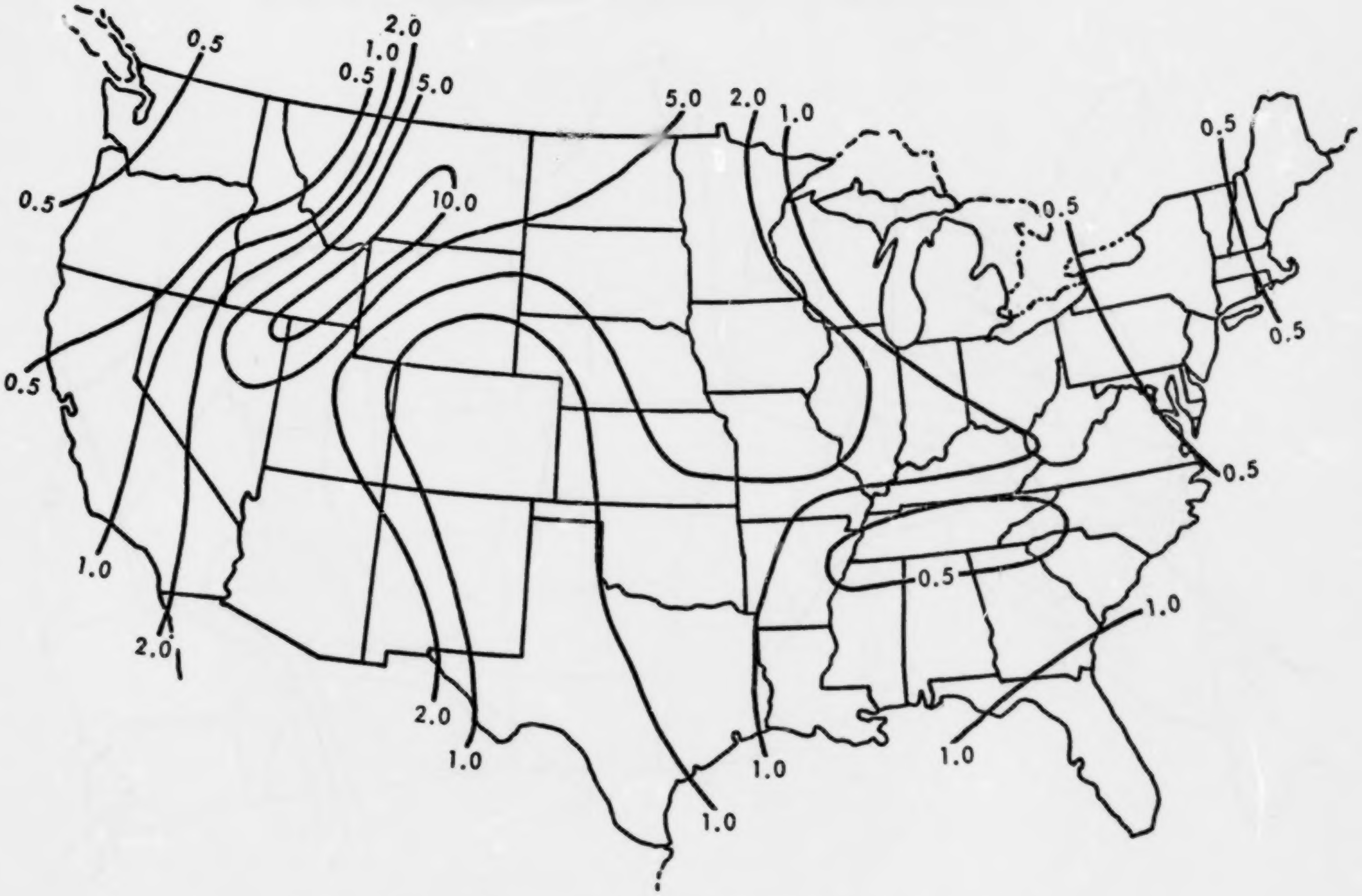

2.0
0.5
1.0
0.5
5.0
5.0
2.0
1.0
0.5
0.5
10.0
0.5
0.5
0.5
0.5
0.5
1.0
2.0
2.0
1.0
1.0
1.0
1.0
1.0
1.0

Figure 12-19. Background alpha radioactivity (picocuries/liter)

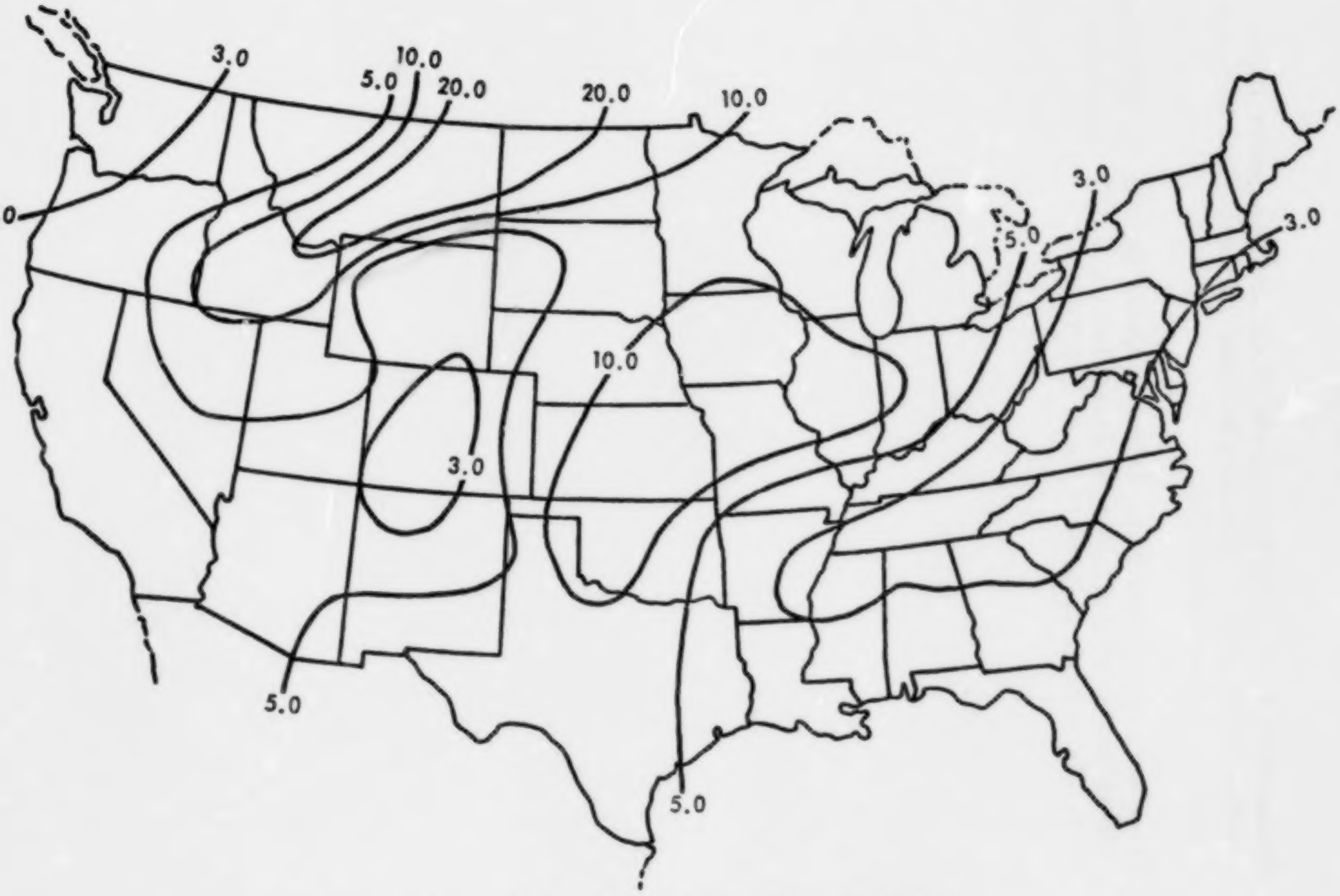

3.0
3.0
5.0
10.0
20.0
20.0
10.0
10.0
3.0
5.0
5.0
3.0
5.0
3.0

Figure 12-20. Background beta radioactivity (picocuries/liter)

REFERENCES

1. Wischmeier, W. H., "Estimating the Cover and Management Factor for Undisturbed Areas," presented at USDA Sediment Yield Workshop, Oxford, Mississippi (1972).

2. Biesecker, J. E., and D. K. Leifste, "Water Quality of Hydrologic Bench-Marks--An Indicator of Water Quality," U.S. Geological Survey Circular 460-E, Washington, D.C. (1973).

GLOSSARY

Active surface mine - A site at which coal (or other mineral associated with pyrite) is being actively mined representing a potential source of acid mine drainage.

Active underground mine - A coal mine (or metal mine associated with pyrite) in active operation. A potential site for generation of acid mine drainage.

Antecedent moisture condition (AMC) - The degree of wetness of a watershed at the beginning of a storm.

Average daily traffic (ADT) - An average valua for the daily vehicular traffic on a specific roadway.

Background - A description of pollutant levels arising from natural sources, and not because of man's utilization of the land.

Base flow - Stream discharge derived from groundwater sources. Sometimes considered to include flows from regulated lakes or reservoirs. Fluctuates much less than storm runoff.

Biochemical oxygen demand (BOD) - The amount of oxygen required by bacteria to stabilize decomposable organic matter under aerobic conditions. Usually the test is limited to 5 days, when it is termed 5-day BOD or BOD_5.

Canopy - The cover of leaves and branches formed by the tops or crowns of plants.

Chemical oxygen demand (COD) - Total quantity of oxygen required for oxidation of organic (carbonaceous) matter to carbon dioxide and water using a strong oxidizing agent (dichromate) under acid conditions.

Commercial forest - The forest which is both available and suitable for growing continuous crops of raw logs or other industrial timber products, and is judged capable of growing at least 20 ft^3 of timber per acre per year.

Conservation Needs Inventory - An inventory, based upon sampling for field surveys, of soil, slope, erosion, land use, and other factors. Needed conservation practices are also recorded. A given percent of an area, generally a county, is sampled. The data are expanded to the entire area.

Consumptive use factor - A factor which measures the amount of water transpired and evaporated during irrigation.

Contour farming - Conducting field operations, such as plowing, planting, cultivating, and harvesting, on the contour.

Contour stripcropping - Layout of crops in comparatively narrow strips in which the farming operations are performed approximately on the contour. Usually strips of grass, close-growing crops, or fallow are alternated with those in cultivated crops.

Cover crop - A close-growing crop grown primarily for the purpose of protecting and improving soil between periods of regular crop production or between trees and vines in orchards and vineyards.

Cover factor "C" - A factor based on a maximum value of 1.0 that reflects the effectiveness of vegetative land cover in controlling erosion. The factor is used in the Universal Soil Loss Equation.

Cover, ground - Any vegetation producing a protecting mat on or just above the soil surface. In forestry, low-growing shrubs, vines, and herbaceous plants under the trees.

Creep - Slow mass movement of soil and soil material down relatively steep slopes primarily under the influence of gravity, but facilitated by saturation with water, strong wind, and by alternate freezing and thawing.

Cross-slope farming - Conducting field operations, such as plowing, planting, cultivating, and harvesting across the general slope of the field.

Curb length - The distance of single street curb, or the length of one side of a street or other thoroughfare. Distinguished from street-length which normally represents two or more curb length.

Curie - A unit of radioactivity equivalent to 3.7×10^{10} disintegrations per second.

Direct runoff - The water that enters the stream channels during a storm or soon after. It may consist of rainfall on the stream surface, surface runoff, and seepage of infiltrated water.

Diversion terrace - Diversions, which differ from terraces in that they consist of individually designed channels across a hillside.

Drainage area - The area draining into a stream at a given point.

Drainage density - Ratio of the total length of all drainage channels in a drainage basin to the area of that basin.

Enrichment ratio - The ratio of concentration of a substance in eroded sediment to that in the soil.

Erosion, rill - An erosion process in which numerous small channels only several inches deep are formed; occurs mainly on recently cultivated soils.

Erosion, sheet - The removal of a fairly uniform layer of soil from the land surface by runoff water.

Field stripcropping - A system of stripcropping in which crops are grown in parallel strips laid out across the general slope but which do not follow the contour. Strips of grass or close-growing crops are alternated with strips of cultivated crops.

Gob pile - Waste material generated during the processing of coal. A potential source of acid mine drainage.

Heavy metal - A metallic (or metallaoid) element of atomic number greater than 20.

Humidity factor - A functional term relating relative humidity, precipitation, saturated vapor pressure, and temperature.

Inactive surface mine - An abandoned or unreclaimed surface mining site at which acid mine drainage may be generated.

Inactive underground mine - An abandoned or inactive underground mine in which acid mine drainage may be generated.

Infiltration - The flow of a liquid into a substance through pores or other openings, connoting flow into a soil.

Irrigation return flow - The return to surface waters of water used to irrigate agricultural land. It consists of tailwater, deep percolation, by-pass water, and canal seepage.

Load index, I - A dimensionless number between 0 and 1.0 reflecting the probability of acid mine drainage from one of four types of sources: active underground, active surface, inactive underground, or inactive surface.

Most probable number (MPN) - A statistical indication of the number of bacteria present in a given volume (usually 100 ml).

Nitrification - The biological oxidation of ammonium salts to nitrites and the further oxidation of nitrites to nitrates.

Nitrogen, available - Usually ammonium, nitrite, and nitrate ions, and certain simple amines are available for plant growth. A small fraction of organic or total nitrogen in the soil is available at any time.

Nutrient, available - That portion of any element or compound in the soil that can be readily absorbed and assimilated by growing plants.

Organic matter (soil) - The organic fraction of the soil that includes plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil population.

Organic nitrogen - "Original" form of nitrogenous nutrients. Gradually converted to ammonia nitrogen and to nitrites and nitrates, if aerobic conditions prevail.

Percolation - The downward movement (or flow), of water through the pores of any substance (such as soil).

Phosphorus, available - Inorganic phosphorus which is readily available for plant growth. Only a small fraction of total phosphorus in the soil is available at any time.

Practice factor "P" - A factor based on a maximum value of 1.0 that reflects the effectiveness of supporting conservation practices in controlling erosion. The factor is used in the Universal Soil Loss Equation.

Pyritic material - Materials containing pyrite (FeS_2). A generic term including other disulfides which can oxidize to form acid mine drainage such as arsenopyrite ($AsFeS_2$) or chalcopyrite ($CuFeS_2$).

Radioactivity, alpha - The spontaneous emission of alpha particles (helium nuclei) by a radioactive substance.

Radioactivity, beta - The spontaneous emission of beta particles (electrons) by a radioactive substance.

Rainfall factor "R" - A numerical expression of rainfall used in the Universal Soil Loss Equation.

Relief - The difference in elevation between the high and low points of a land surface.

Relief ratio - The ratio between the relief of watershed and the maximum length of watershed.

Rill - A small, intermittent watercourse with steep sides, usually only a few inches deep and, hence, no obstacle to tillage operations.

Root zone - The part of the soil that is penetrated or can be penetrated by plant roots.

Runoff - That portion of the precipitation on a drainage area that is discharged from the area in stream channels. Types include surface runoff, groundwater runoff, or seepage.

Runoff, urban - The flow of waters in urban areas from precipitation or thaw incidents from gutters into street inlets or from other connections into storm or combined-sewer system.

Sediment yield - The quantity of sediment, measured in dry weight or by volume, transported through a stream cross-section in a given time.

Sediment delivery ratio - The fraction of the soil eroded from upland sources that actually reaches a point of measurement or estimation.

Slope length factor "L" - A factor used in the Universal Soil Loss Equation to reflect relative effect of slope length on soil erosion. Slope length is defined as the average distance, in feet, from the point of origin of overland flow to whichever of the following limiting conditions occurs first: (a) the point where slope decreases to the extent that deposition begins or (b) the point where runoff enters well-defined channels.

Slope steepness factor "S" - A factor used in the Universal Soil Loss Equation to represent relative effect of slope gradient on soil erosion. Slope gradient is defined as the degree of deviation of a surface from the horizontal, in percent.

Soil erodibility factor "K" - A factor used in the Universal Soil Loss Equation to reflect relative basic erodibility differences of soils.

Soil texture - The relative proportions of the three broad particle size classifications: sand, silt, and clay, in a soil mass.

Tailings pile - Residues generated during the beneficiation of metal ores. If material is pyritic, it is a potential source of acid mine drainage.

Terrace - An embankment or combination of an embankment and channel constructed across a slope to control erosion by diverting or storing surface runoff instead of permitting it to flow uninterrupted down the slope.

Topographic factor "LS" - A dimensionless factor used in the Universal Soil Loss Equation to represent the combined effects of slope length and steepness.

Total dissolved solids - The dissolved salt loading in surface and subsurface waters. Equivalent to salinity.

SYMBOLS

A	Source area, ha
AMD	Acid mine drainage
AS; AU	Active surface or underground mine
AX	Average number of axles per vehicle
BG	Background source
C	Cover management factor
$C_s(i)$	Concentration of pollutant i in sediment
$C(i)_{source}$	Concentration, C of pollutant i in source
$C(Alk)_{BG}$	Concentration of background alkalinity, mg/liter
CL	Curb-length density, m/ha
CU	Annual consumptive use of water, cm/year
D	Overland distance between erosion site and receptor water, ft
DD	Drainage density, km^{-1}
DI	Amount of deicer applied in the area, kg/year
DI_{30}	30-Day maximum, DI
E	Annual average erosion rate, MT/ha/year
f_N	Ratio of NA:NT in eroded sediment
f_P	Ratio of PA:PT in eroded sediment
FL	Small feedlot source
FL_d	Feedlot delivery ratio
H	Humidity factor

HIF	Herbicide, Insecticide, Fungicide; any pesticide
HM	Heavy metals
I	Load index for acid mine drainage
IRF	Irrigation return flow
IRR	Irrigated water added annually to crop root zone, cm/year
IS; IU	Inactive surface or underground mine
K	Soil erodibility factor
L	Slope length factor
L_{st}	Street length, km
L(S)	Daily street solids loading rate, kg/curb-km/day
LF; LF_d	Landfill, landfill delivery ratio
LH	Length of highway section, km
LS	Topographic factor
λ (Lambda)	Slope length, m
NA	Available (or mineralized) nitrogen
N_{Pr}	Nitrogen yield rate per unit area from precipitation, kg/ha/year
NT	Sum of nitrogen of all chemical forms
OM	Organic matter
OR	Overland runoff
p	Percolation rate, cm/year
P	Conservation practice factor
Pr	Annual average precipitation, cm/year, storm precipitation, cm

PA	Available phosphorus
PD	Population density, number/ha
PT	Total phosphorus; also point source
Q_i; Q	Runoff due to a storm event, cm
Q(FL)	Feedlot runoff, cm/year
Q(LF)	Landfill leachate flow rate, cm/year
Q(OR)	Overland runoff, cm/year
Q(P)	Total precipitation flow rate, cm/year
Q(Perc)	Percolation flow rate, cm/year
Q(R)	Direct runoff, cm/year
Q(Str)	Stream flow rate, liters/sec
Q(t)	Runoff over a period of time, t
R	Rainfall erosivity factor
R_r	Rainfall erosivity factor due to rainfall
R_s	Rainfall erosivity factor due to snowmelt
RAD	Radioactivity
RH	Relative humidity, %
r_N	Enrichment ratio for nitrogen (ratio of concentration of nitrogen in sediment to that in soil)
r_{OM}	Enrichment ratio for organic matter (ratio of concentration of organic matter in sediment to that in soil)
r_p	Enrichment ratio for phosphorus (ratio of concentration of phosphorus in sediment to that in soil)
S	Slope gradient factor; also sediment

S_d	Sediment delivery ratio (ratio of the amount of sediment delivered to a stream to the amount of on-site erosion)
SD	Number of snow days
SD_{30}	Thirty-day maximum SD
SVP_t	Saturated vapor pressure at given temperature, mm Hg
T	Annual average temperature, °C
TD	Traffic density, number of vehicles/day
TDS	Total dissolved solids
U	Composite topographic factor for irregular slopes
$y(i)_{tr}$	Traffic related pollutant i, kg/axle-km/day
Y(AMD)	Acid mine drainage loading, kg/year
Y(DI)	Deicing salt loading, kg/year
Y(HIF)	Total pesticide loading, kg/year
Y(HM)	Heavy metal loading, kg/year
$Y(i)_{FL}$	Loading of pollutant i from small feedlots, kg/year
$Y(i)_{LF}$	Loading of pollutant i from landfills, kg/year
$Y(i)_{tr}$	Loading of pollutant i from traffic sources, kg/year
$Y(i)_U$	Loading of pollutant i from urban areas, kg/year
$Y(N)_{Pr}$	Nitrogen loading from precipitation runoff, kg/year
Y(NA)	Available nitrogen loading, kg/year
$Y(NT)_E$	Total nitrogen loading from erosion, kg/year
$Y(OM)_E$	Organic matter loading, kg/year

$Y(PA)$	Available phosphorus loading, kg/year
$Y(PT)$	Total phosphorus loading, kg/year
$Y(RAD)$	Loading of radioactive substances, microcuries/year
$Y(S)_E$	Sediment loading from surface erosion, MT/year
$Y(S)_U$	Loading of street solids from urban areas, kg/year
$Y(TDS)_{BG}$	Salinity (TDS) load from background, kg/year
$Y(TDS)_{IRF}$	Salinity (TDS) load in irrigation return flow, kg/year
$Y(TDS)_{PT}$	Salinity (TDS) load from point sources, kg/year
$Y(i)_{BG}$	Yield of pollutant i from background, kg/year

APPENDIX A

MONTHLY DISTRIBUTION OF RAINFALL EROSIVITY FACTOR R

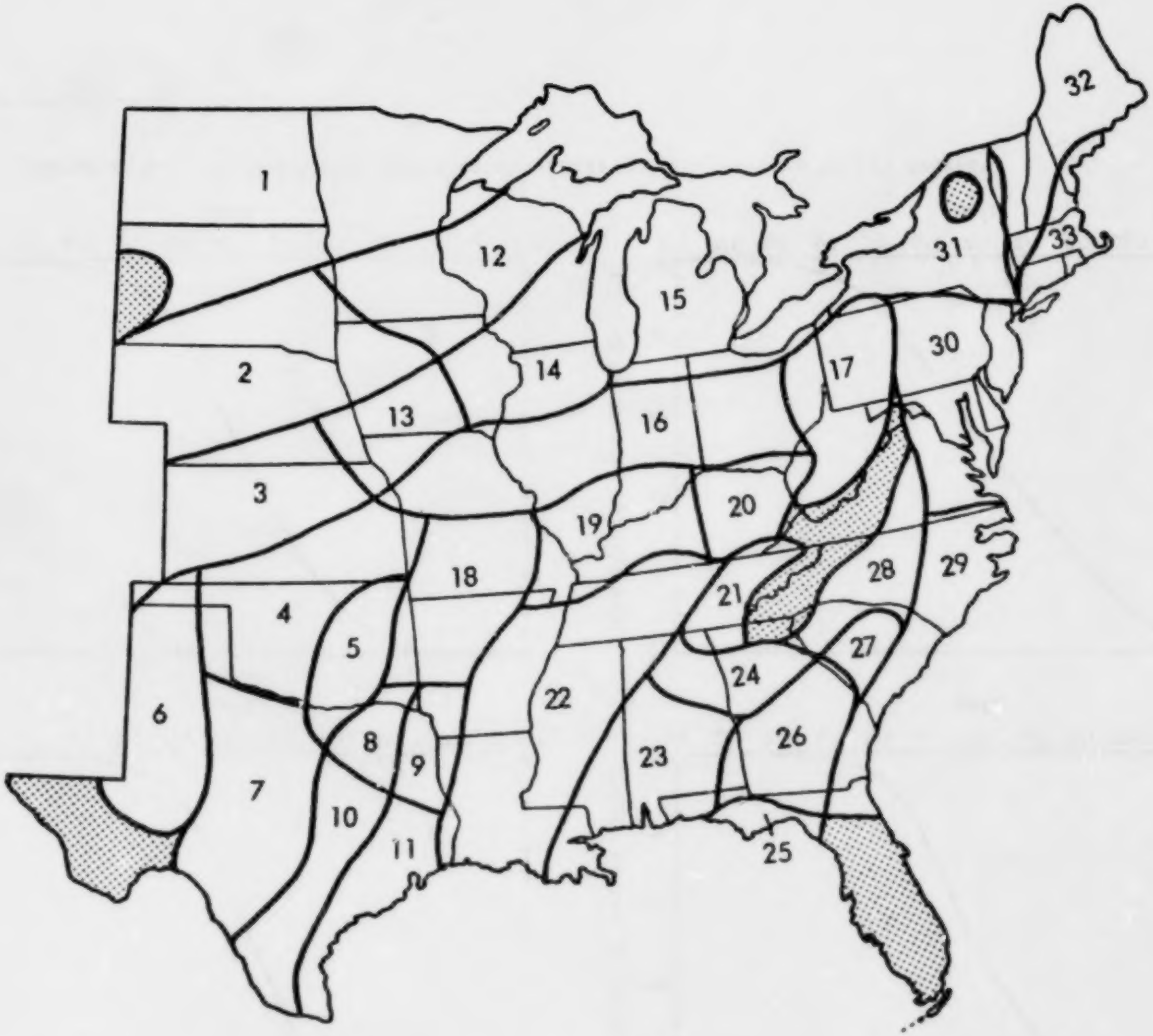
- Distribution Curves for the Eastern United States

  Figure A-1 - Key Map for Selection of Distribution Curve

  Figure A-2a through A-2i - Distribution Curves

- Distribution Curves for Hawaii (Figures A-3a through A-3c)

- Methods for Developing R Distribution Curves for the Western United States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31
32
33

Figure A-1. Key map for selection of applicable erosion-index distribution curve*

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* Wischmeier, W. H., and D. D. Smith, "Predicting Rainfall--Erosion Losses from Cropland East of the Rocky Mountains," Agricultural Handbook 282, U.S. Department of Agriculture, Agriculture Research Service, May 1965.

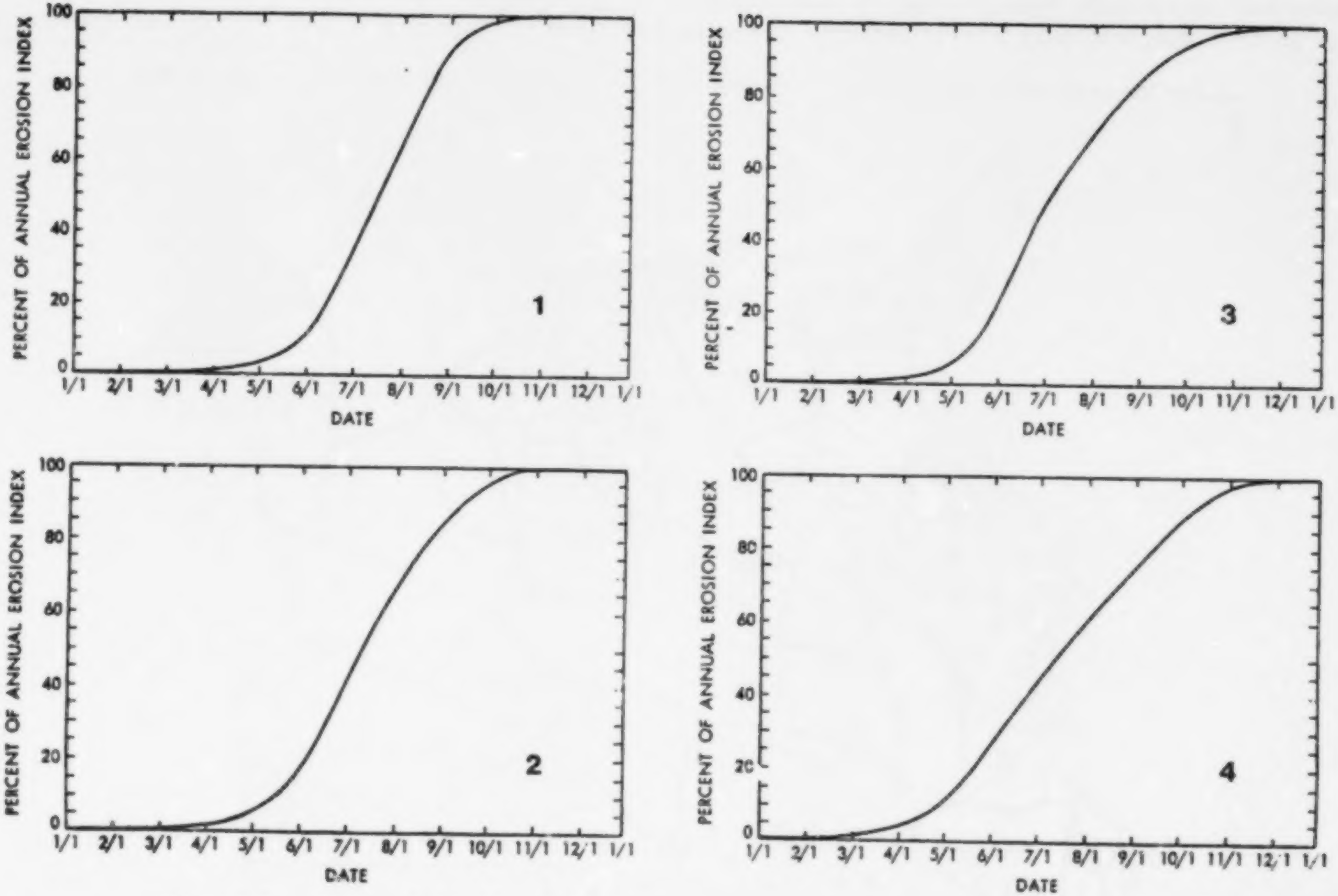

Figure A-2a. Erosion-index distribution curves for the eastern United States*

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* ibid.

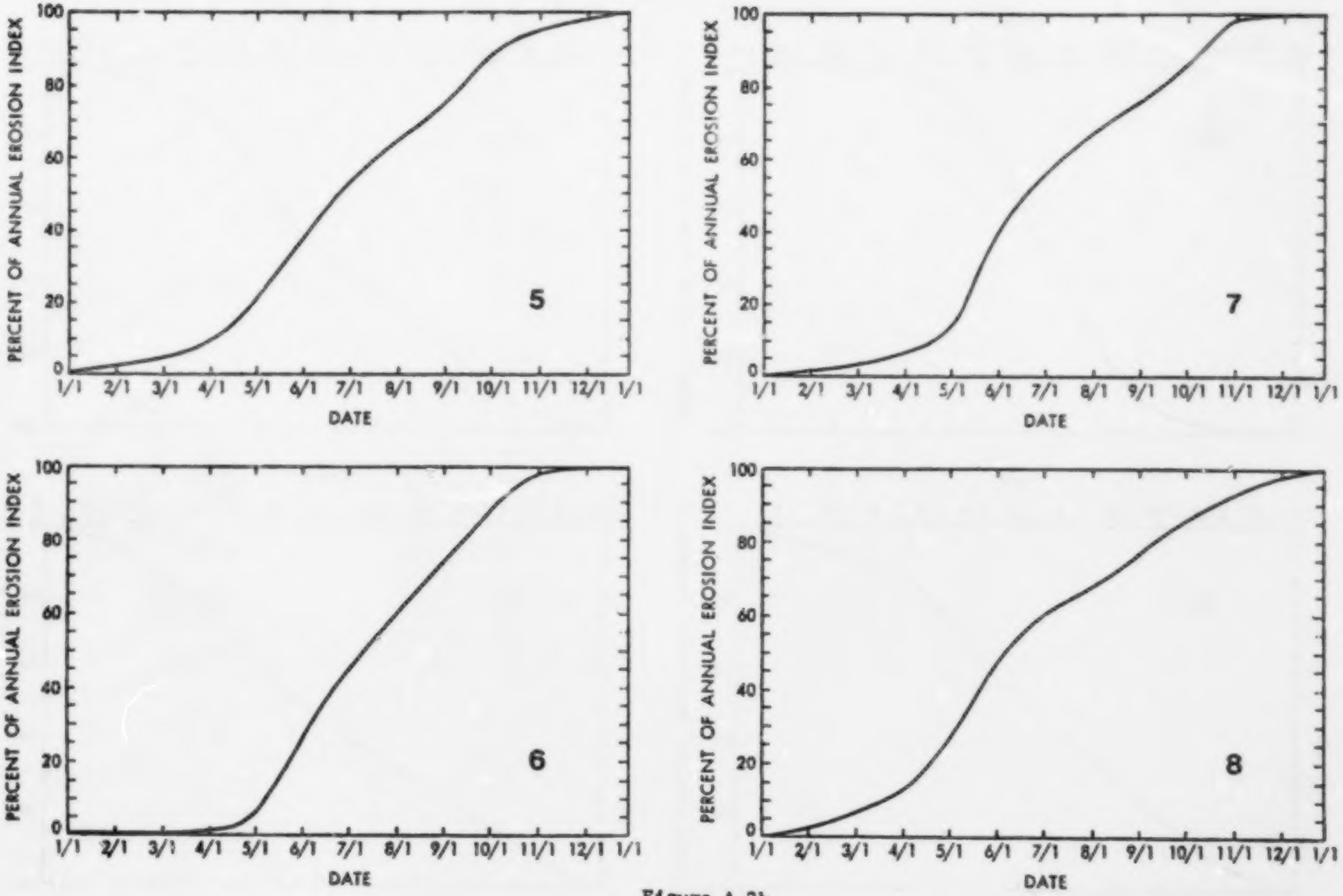

5
7
6
8
PERCENT OF ANNUAL EROSION INDEX
0
20
40
60
80
100
DATE
1/1
2/1
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
1/1

Figure A-2b

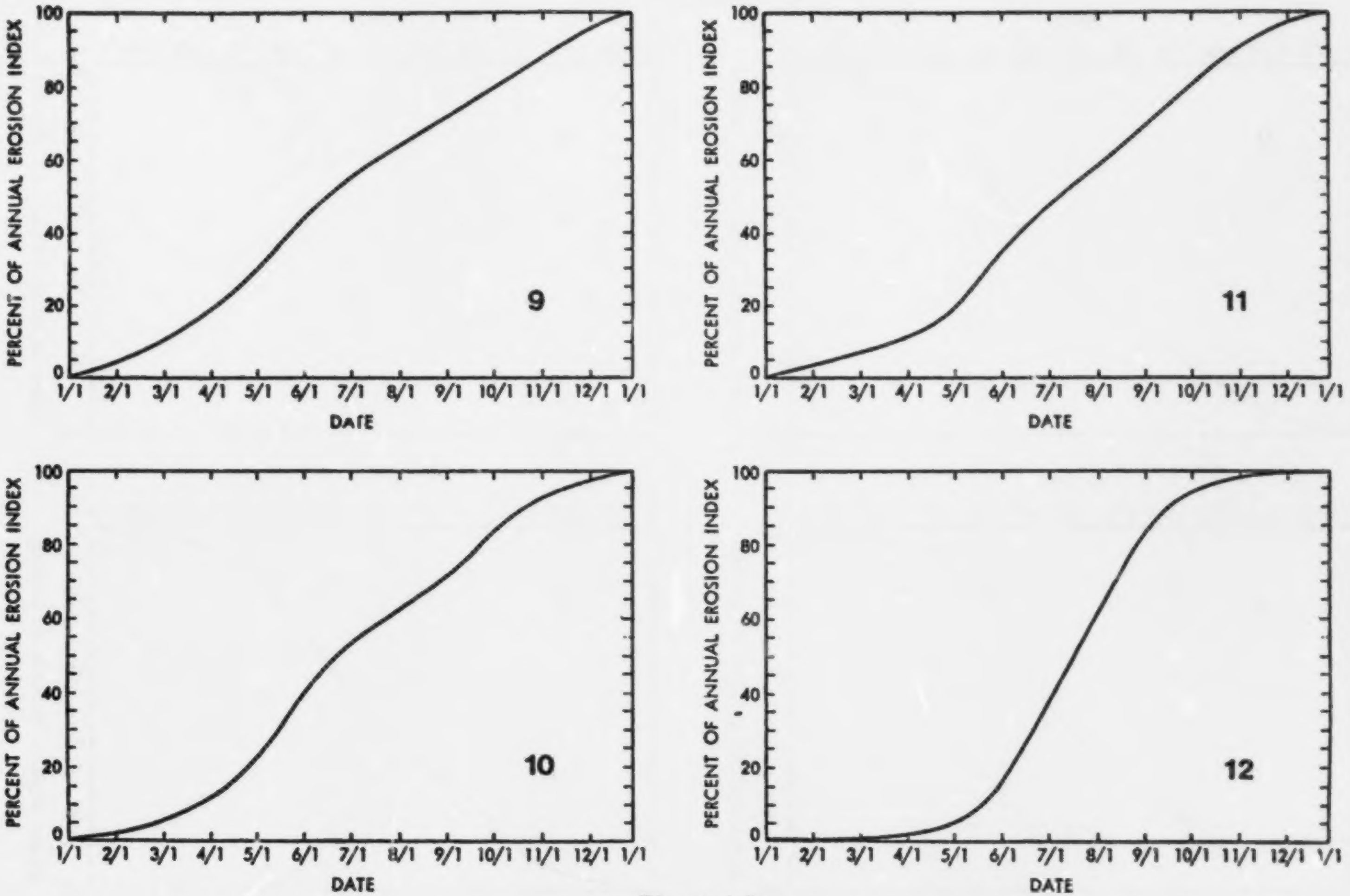

PERCENT OF ANNUAL EROSION INDEX
0
20
40
60
80
100
1/1
2/1
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
1/1
DATE
9
11
10
12

Figure A-2c

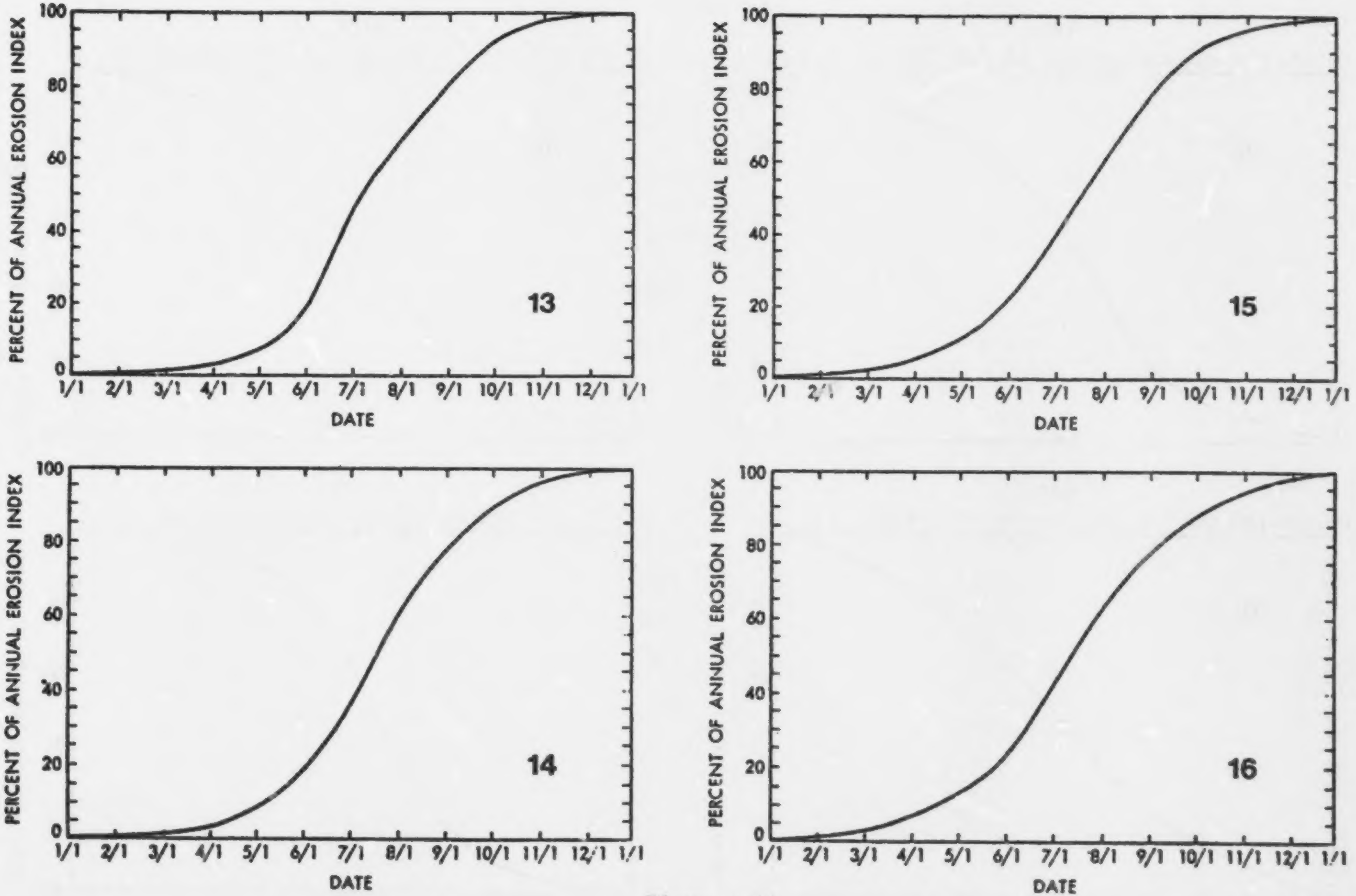

13
15
14
16
PERCENT OF ANNUAL EROSION INDEX
0
20
40
60
80
100
DATE
1/1
2/1
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
1/1

Figure A-2d

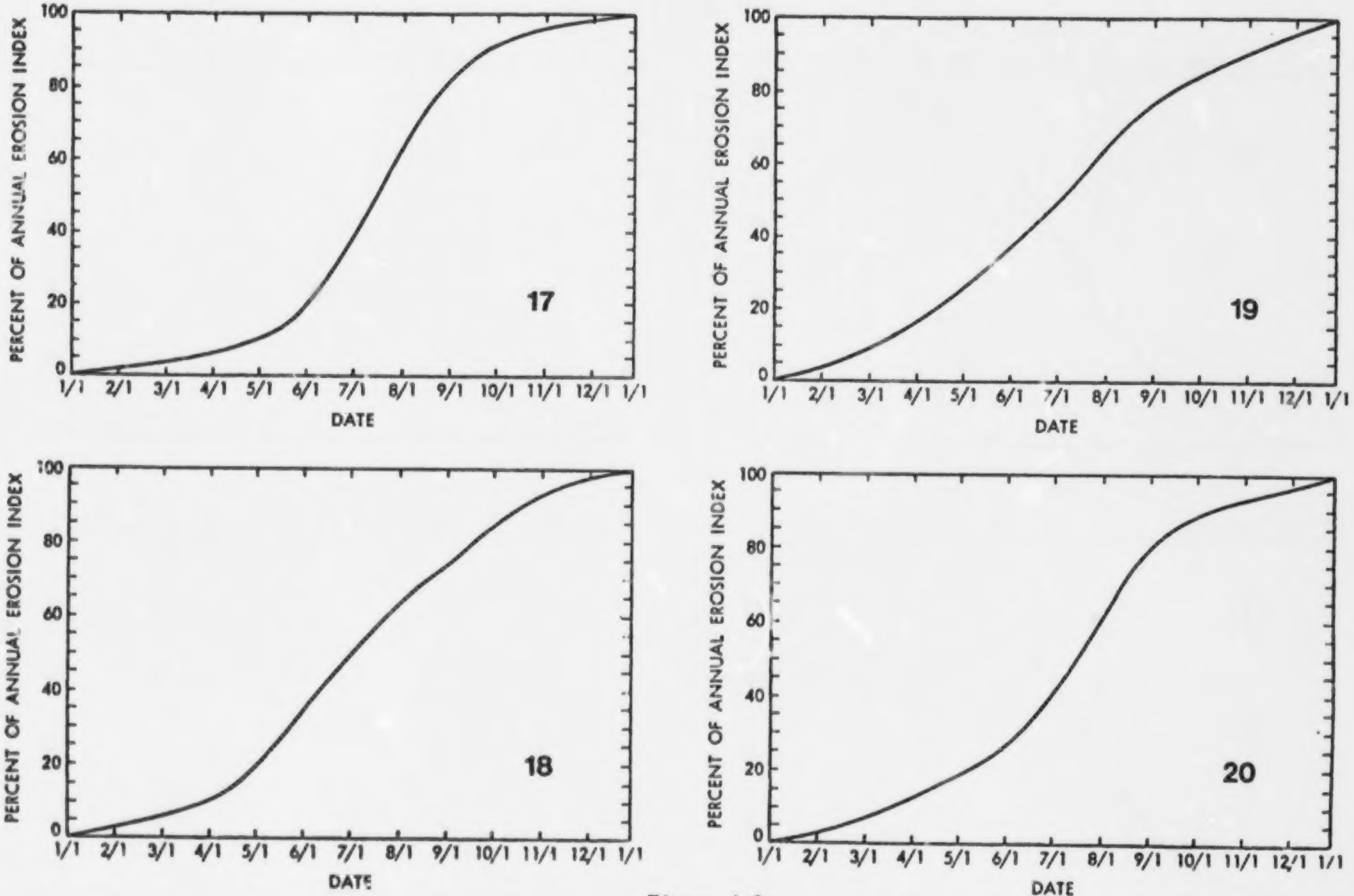

17
18
19
20
PERCENT OF ANNUAL EROSION INDEX
0
20
40
60
80
100
DATE
1/1
2/1
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
1/1

Figure A-2e

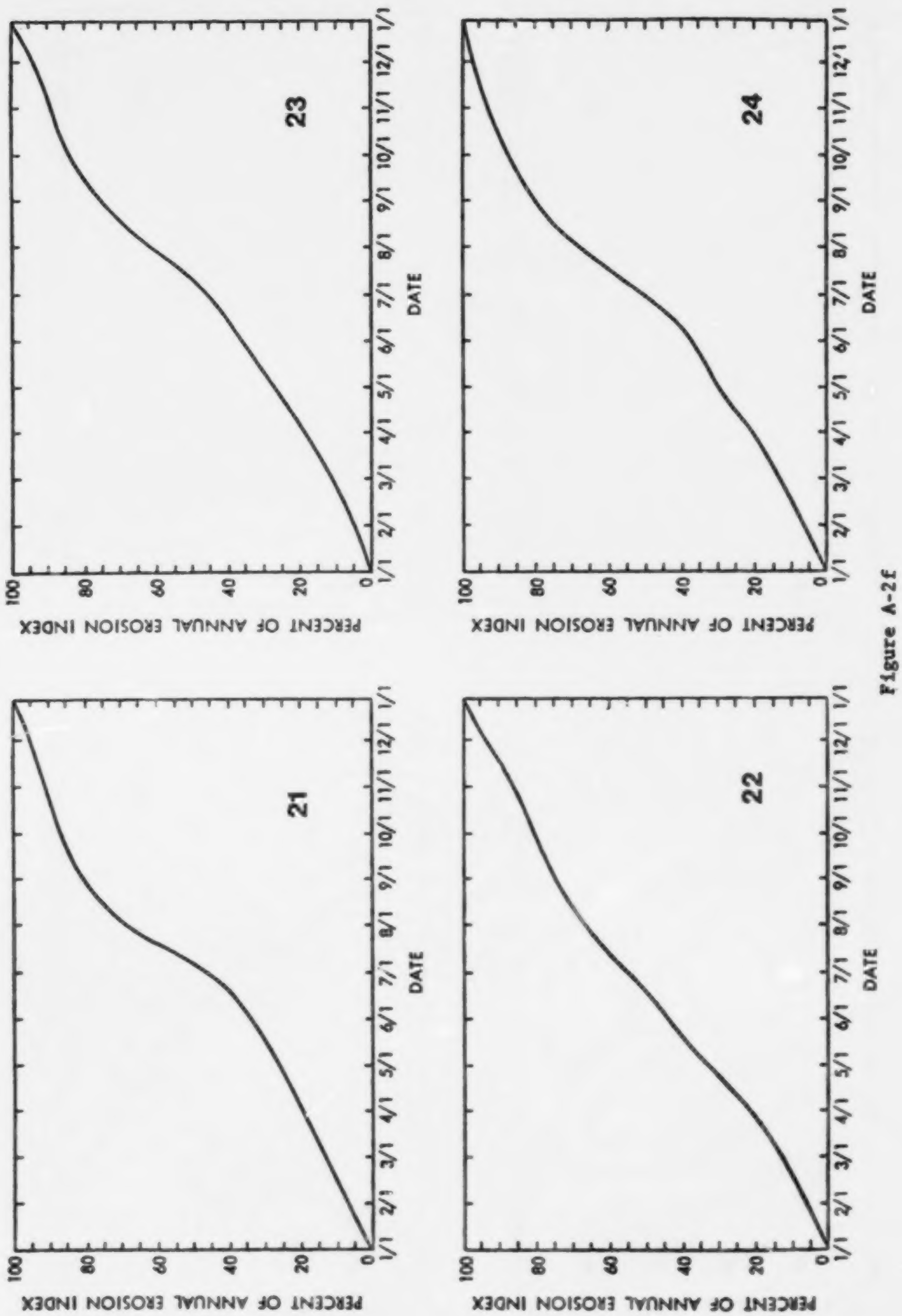

21
22
23
24
PERCENT OF ANNUAL EROSION INDEX
0
20
40
60
80
100
DATE
1/1
2/1
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
1/1

Figure A-2f

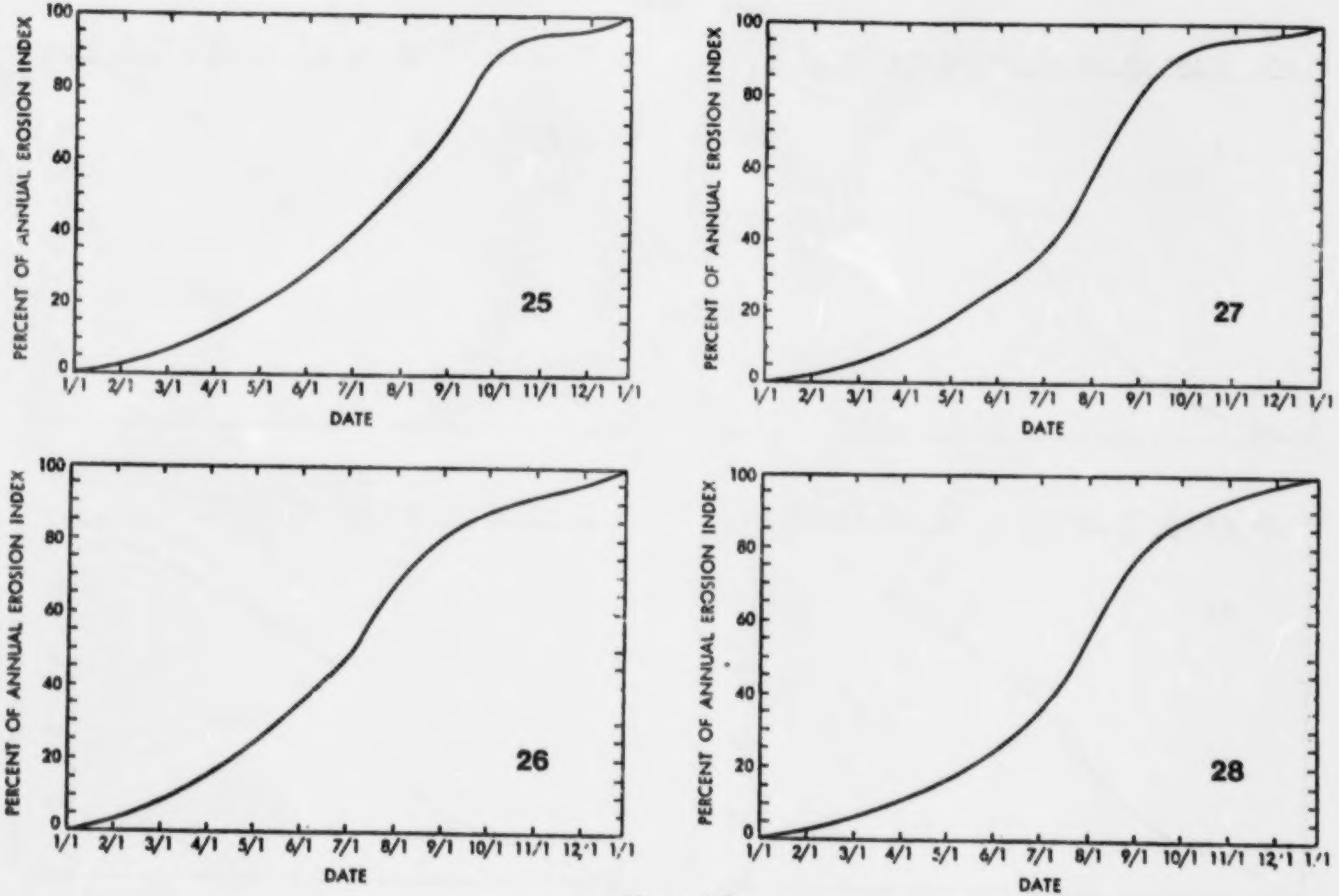

25
27
26
28
PERCENT OF ANNUAL EROSION INDEX
0
20
40
60
80
100
1/1
2/1
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
1/1
DATE

Figure A-2g

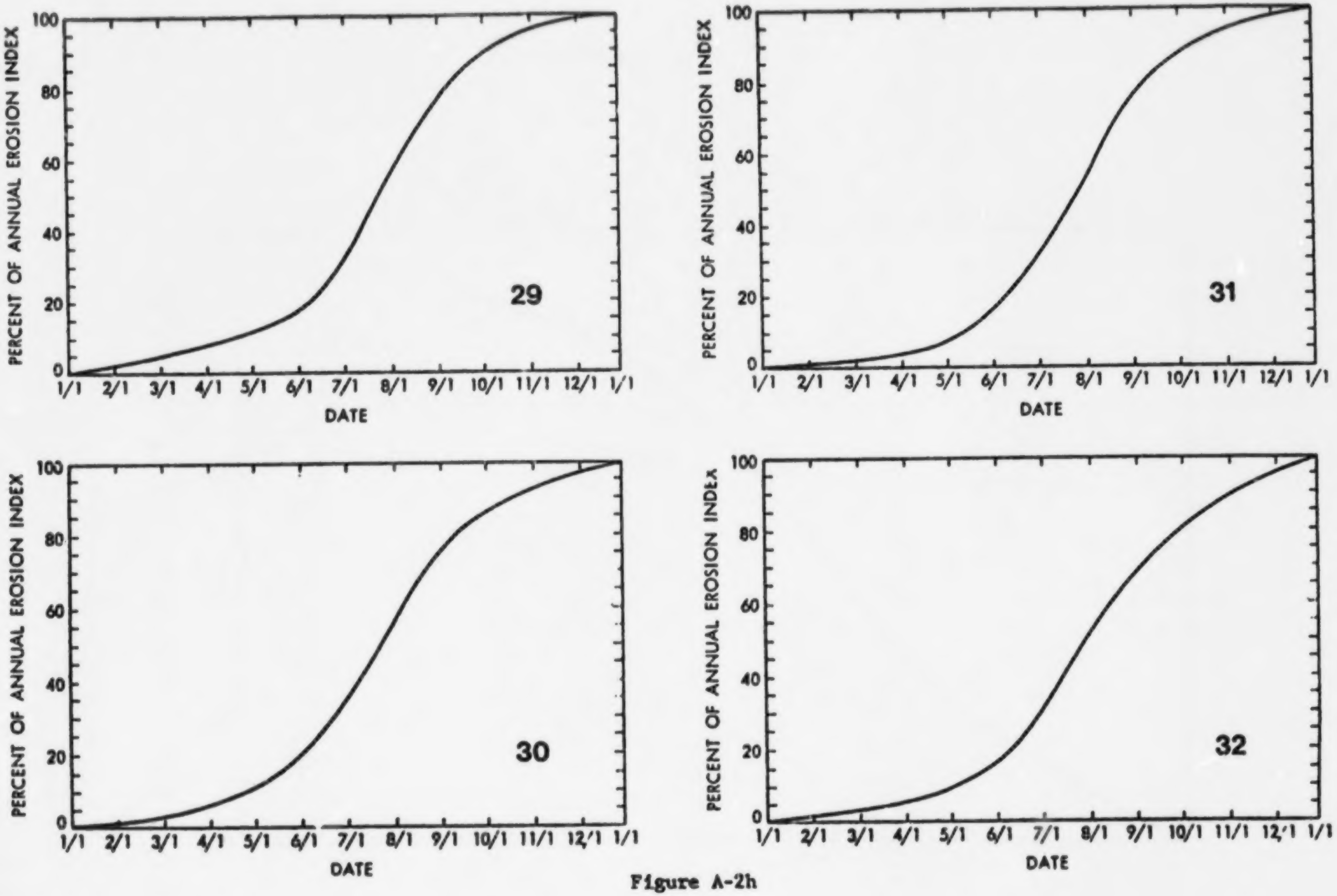
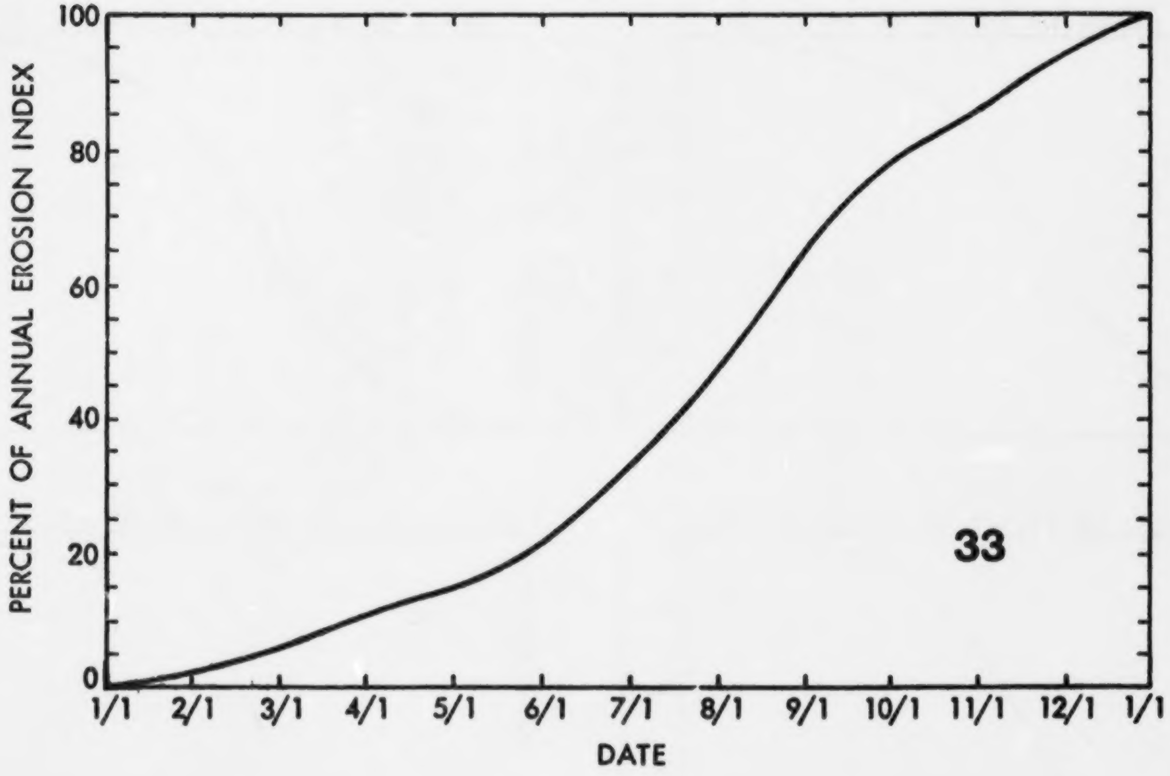

PERCENT OF ANNUAL EROSION INDEX
100
80
60
40
20
0
1/1 2/1 3/1 4/1 5/1 6/1 7/1 8/1 9/1 10/1 11/1 12/1 1/1
DATE
29
31
30
32

Figure A-2h



100
80
60
40
20
0
PERCENT OF ANNUAL EROSION INDEX
1/1
2/1
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
1/1
DATE
33

Figure A-21

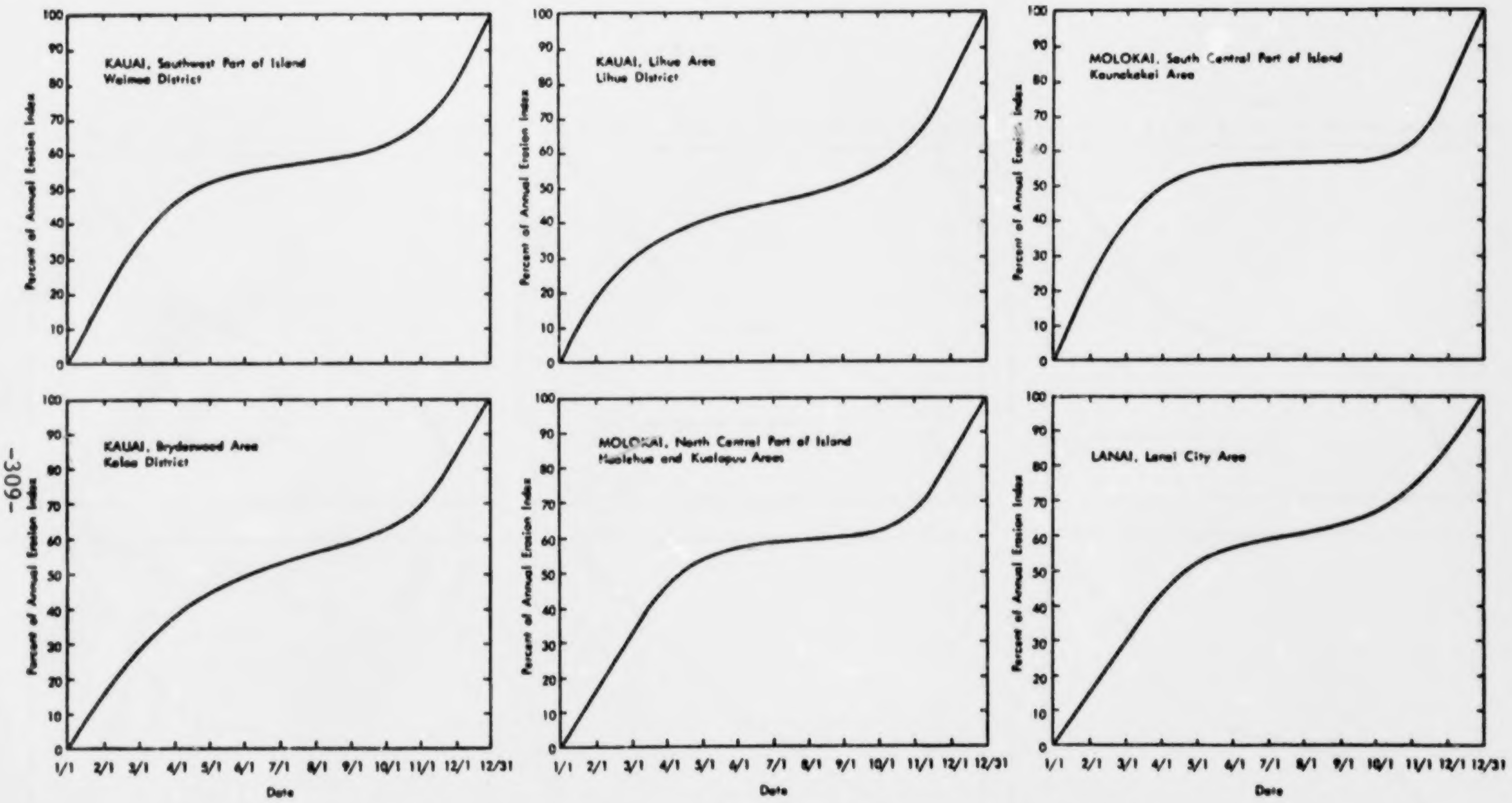


Figure A-3a. Erosion-index distribution curves for Hawaii*

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* Soils Technical Note No. 3, U.S. Department of Agriculture, Soil Conservation Service, Honolulu, Hawaii, May 1974.

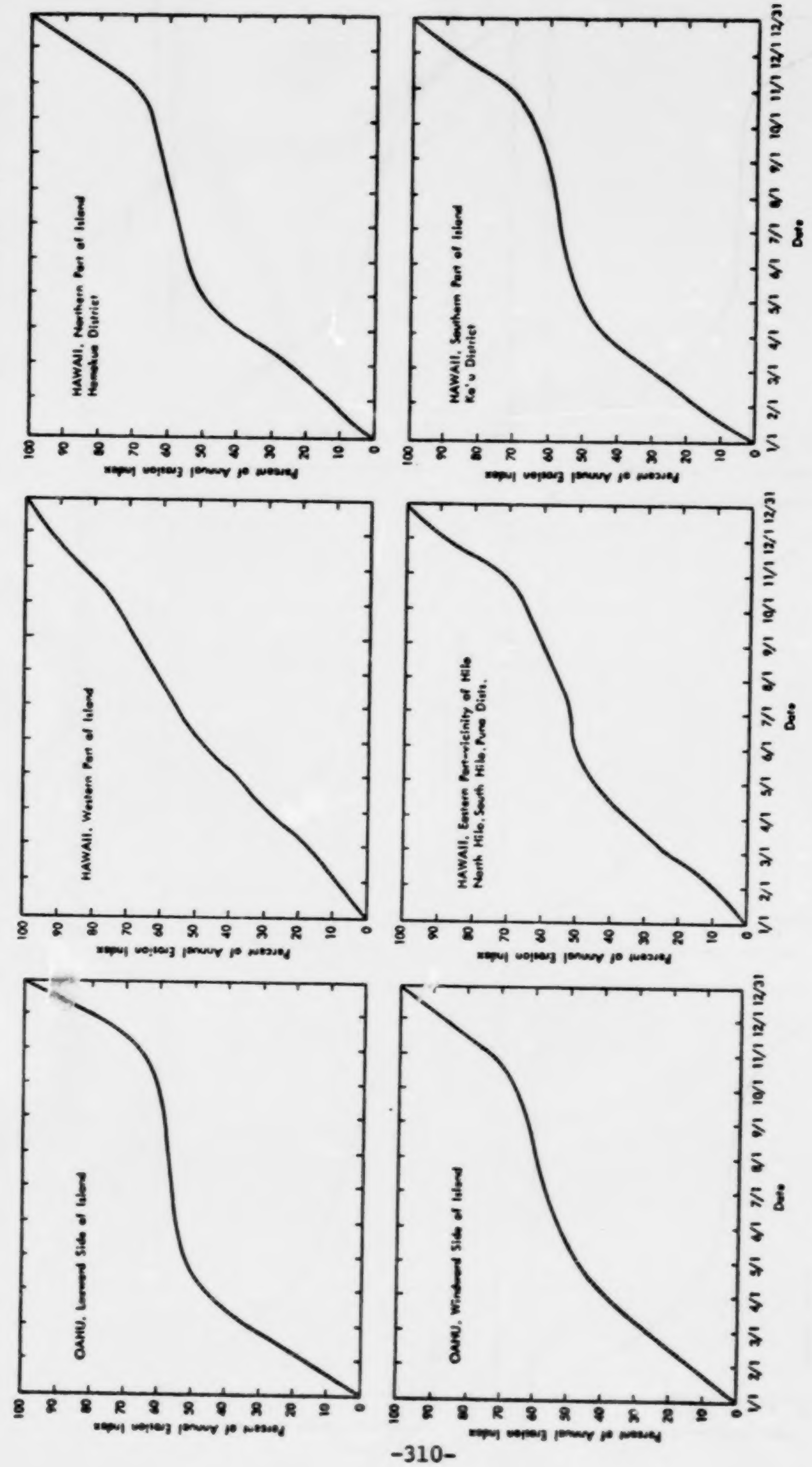
OAHU, Leeward Side of Island
OAHU, Windward Side of Island
HAWAII, Western Part of Island
HAWAII, Eastern Part-vicinity of Hilo
North Hilo, South Hilo, Puna Dists.
HAWAII, Northern Part of Island
Hamakua District
HAWAII, Southern Part of Island
Ka'u District
Percent of Annual Erosion Index
0
10
20
30
40
50
60
70
80
90
100
Date
1/1
2/1
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
12/31

Figure A-3b

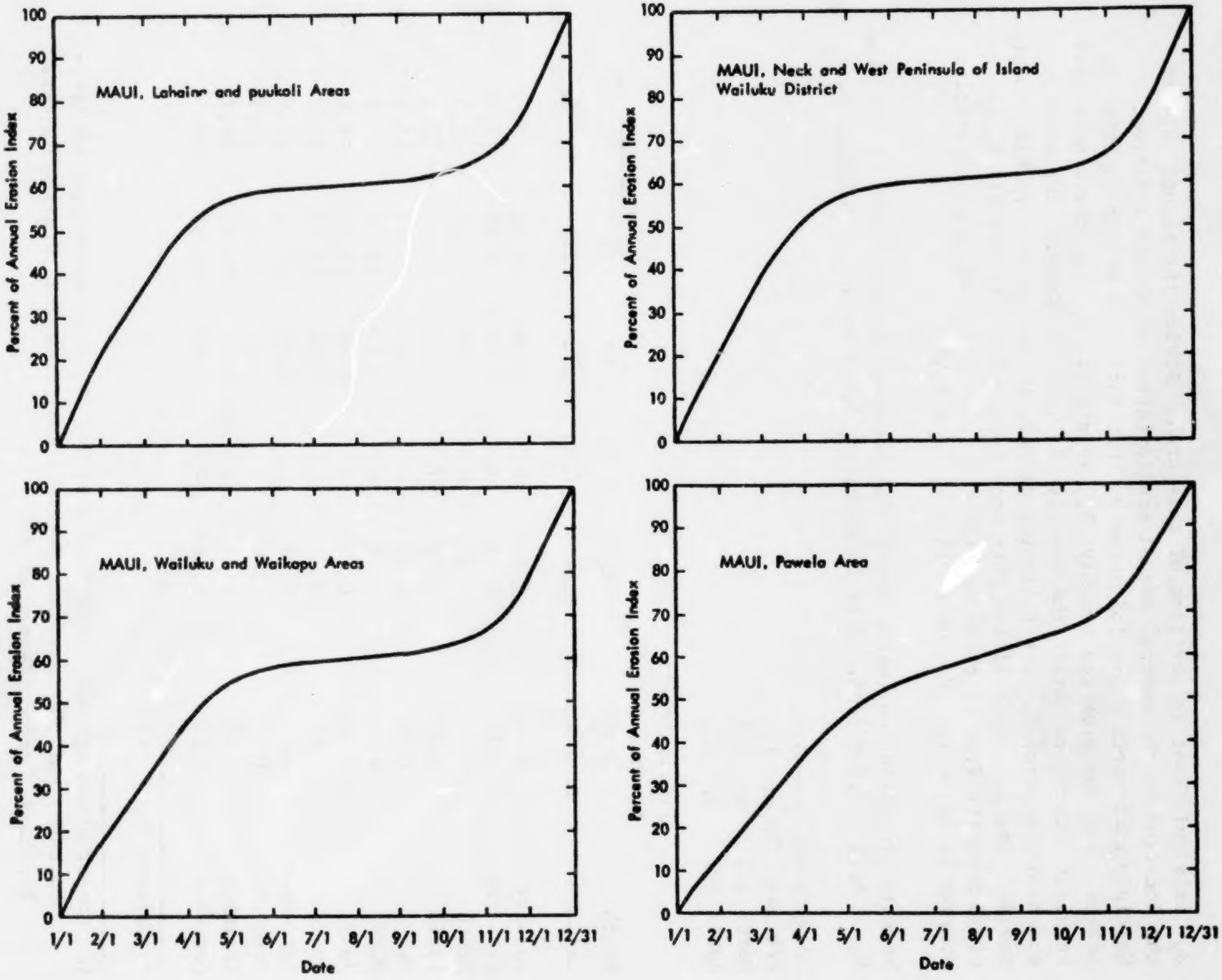
MAUI, Lahaine and puukoli Areas
MAUI, Neck and West Peninsula of Island
Wailuku District
MAUI, Wailuku and Waikapu Areas
MAUI, Pawela Area
Percent of Annual Erosion Index
0
10
20
30
40
50
60
70
80
90
100
Date
1/1
2/1
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
12/31

Figure A-3c

METHODS FOR DEVELOPING R DISTRIBUTION CURVES FOR THE WESTERN UNITED STATES[1/]

R_s is significant in portions of this area. Divide the annual R_T for the location by the average annual precipitation to obtain a factor. Multiply each month's precipitation by this factor to obtain monthly R_T values. Add the prorated monthly R_s values to R_T for the months when snowmelt occurs, to obtain the monthly R values. Compute the monthly accumulative percent. The following example is for Hylton, in Elko County, Nevada. The 2-6 rainfall for this area is 0.9 in. The annual R_T determined from the Type II curve on Figure 3-4, is 18. Annual precipitation average is 12.72 in. Factor is 18 ÷ 12.72 = 1.42.

Monthly precipitation (water depth) for December through March is 4.92 in. R_s = 4.92 x 1.5 = 7.38. This is prorated, based on local judgment to

January 10%	or	0.7
February 20%	or	1.5
March 50%	or	3.7
April 20%	or	1.5

Month (1)	Precipitation (inches water depth) (2)	R_T (3)	R_s (4)	R* (5)	Cumulative R (6)	Cumulative % (7)
January	1.18	1.68	0.7	2.38	2.38	0.093
February	1.14	1.62	1.5	3.12	5.50	21.6
March	1.29	1.83	3.7	5.53	11.03	43.3
April	1.49	2.12	1.5	3.62	14.65	57.5
May	1.48	2.10	-	2.10	16.75	65.8
June	0.91	1.29	-	1.29	18.04	70.9
July	0.63	0.89	-	0.89	18.93	74.4
August	0.52	0.74	-	0.74	19.67	77.3
September	0.63	0.89	-	0.89	20.56	80.8
October	1.17	1.66	-	1.66	22.22	87.3
November	0.97	1.38	-	1.38	23.60	92.7
December	1.31	1.86	-	1.86	25.46	100

* Columns (3) + (4).

[1/] Conservation Agronomy Technical Note No. 32, U.S. Department of Agriculture, Soil Conservation Service, West Technical Service Center, Portland, Oregon, September 1974.

Values in cumulative percent column (7) are the points used in plotting the monthly R distribution curve.

For A-2, A-3, and A-4 Areas Shown in Figure 3-4

R_s is not significant in most parts of these areas. Use the monthly rainfall distribution as the R distribution. Simply accumulate monthly precipitation amounts and divide each by the annual precipitation. The results obtained for each month will be the points for plotting the monthly R distribution curve.

For B-1 and C Areas Shown in Figure 3-4

R_s in most parts of these areas is significant.

1. "Multipliers" are used to time average monthly precipitation amounts. Sum the results of multiplications to obtain the "factored annual precipitation." Divide the annual R_r for the location by the "factored annual precipitation" to obtain a factor which will be used to convert monthly precipitation amounts to the monthly R values (see the previous section for A-1 area). Values of multipliers are:

Month(s)	Multipliers
January, February, March	0.1
April	1.0
May	4.0
June, July, August	7.0
September, October	2.0
November, December	0.1

2. Add the prorated R_s values to the months when the snowmelt occurs to obtain the monthly R values. Compute the monthly accumulative percents which are points used in plotting the monthly R distribution curve. The following example is for a hypothetical area which has an annual rainfall factor R_r of 25, and a R_s factor of 7.5 (4.94 x 1.5 rounded to 7.5). The 4.94 in. is total precipitation for December, January, February, and March. R_s factor is prorated to:

January	0%	or	0 in.
February	33.3%	or	2.5 in.
March	33.3%	or	2.5 in.
April	33.3%	or	2.5 in.

Month (1)	Precipitation (in.) (2)	Multiplier (3)	Factored monthly pptn. (Col 2 x Col. 3) (4)	Monthly R_r* (5)
January	1.33	0.1	0.13	0.11
February	1.14	0.1	0.11	0.09
March	1.35	0.1	0.13	0.11
April	1.48	1.0	1.48	1.24
May	1.43	4.0	5.72	4.80
June	1.00	7.0	7.00	5.78
July	0.80	7.0	5.60	4.69
August	0.78	7.0	5.46	4.58
September	0.85	2.0	1.70	1.43
October	1.14	2.0	2.28	1.91
November	0.92	0.1	0.09	0.08
December	1.12	0.1	0.11	0.09
Total	13.34		29.81	25.0

Month	Monthly R_s	Monthly R $=R_r + R_s$	Cumulative	
			R	%
(1)	(6)	(7)	(8)	(9)
January	--	0.11	0.1	--
February	2.5	2.59	2.7	8
March	2.5	2.66	5.4	17
April	2.5	3.74	9.1	28
May	--	4.80	13.9	43
June	--	5,87	19.8	61
July	--	4.69	24.5	75
August	--	4.58	29.0	89
September	--	1.43	30.5	94
October	--	1.91	32.4	99
November	--	0.08	32.4	100
December	--	0.09	32.5	100
Total	7.5	32.5		

---

* In this example, the calculated factor value is 0.84 (25 ÷ 29.81). Monthly R_r is obtained by multiplying each "factored monthly pptn." with 0.84.

For B-2 Area Shown in Figure 3-3

In this area, no R_s values are needed. Follow the same procedure and use the same set of multipliers as the preceding section for areas B-1 and C, except that steps for obtaining monthly R_s values are not used. The cumulative R and cumulative percent are computed from monthly R_r (column 5 in the preceding example).

APPENDIX B

METHODS FOR PREDICTING SOIL ERODIBILITY INDEX K

- Nomograph for predicting K values of surface soils using chemical and physical parameters.

- Nomograph for predicting K values of high clay subsoils using chemical mineralogical and physical parameters.

NOMOGRAPH FOR PREDICTING K VALUES OF SURFACE SOIL

In 1971 Wischmeier et al.[1] presented a soil erodibility nomograph derived from statistical analysis of 55 soil types. Five soil parameters are included in the nomograph to predict erodibility: percent silt plus very fine sand; percent sand greater than 0.10 millimeter; organic matter content; soil structure; and permeability. Values of the parameters may be obtained from routine laboratory determinations and standard soil profile descriptions.

The nomograph is reproduced here as Figure B-1.

Description of Factors[2]

Grain size distribution

Grain size distribution has a major influence on a soil's erodibility: the greater the silt content, the greater the soil's erodibility; the smaller the sand content, the greater the soil's erodibility.

Particles in the very fine sand classification behave more like silt than sand. Therefore, the percentage of very fine sand should be subtracted from the total percentage of sand and added to the percentage of silt.

---

[1] Wischmeier, W. H., C. B. Johnson, and B. U. Cross, "A Soil Erodibility Nomograph for Farmland and Construction Sites," J. Soil and Water Conservation, 26:189-193 (1971).

[2] "Technical Guide to Erosion and Sediment Control Design (Draft)," Water Resources Administration, Maryland Department of Natural Resources, Annapolis, Maryland, September 1973.

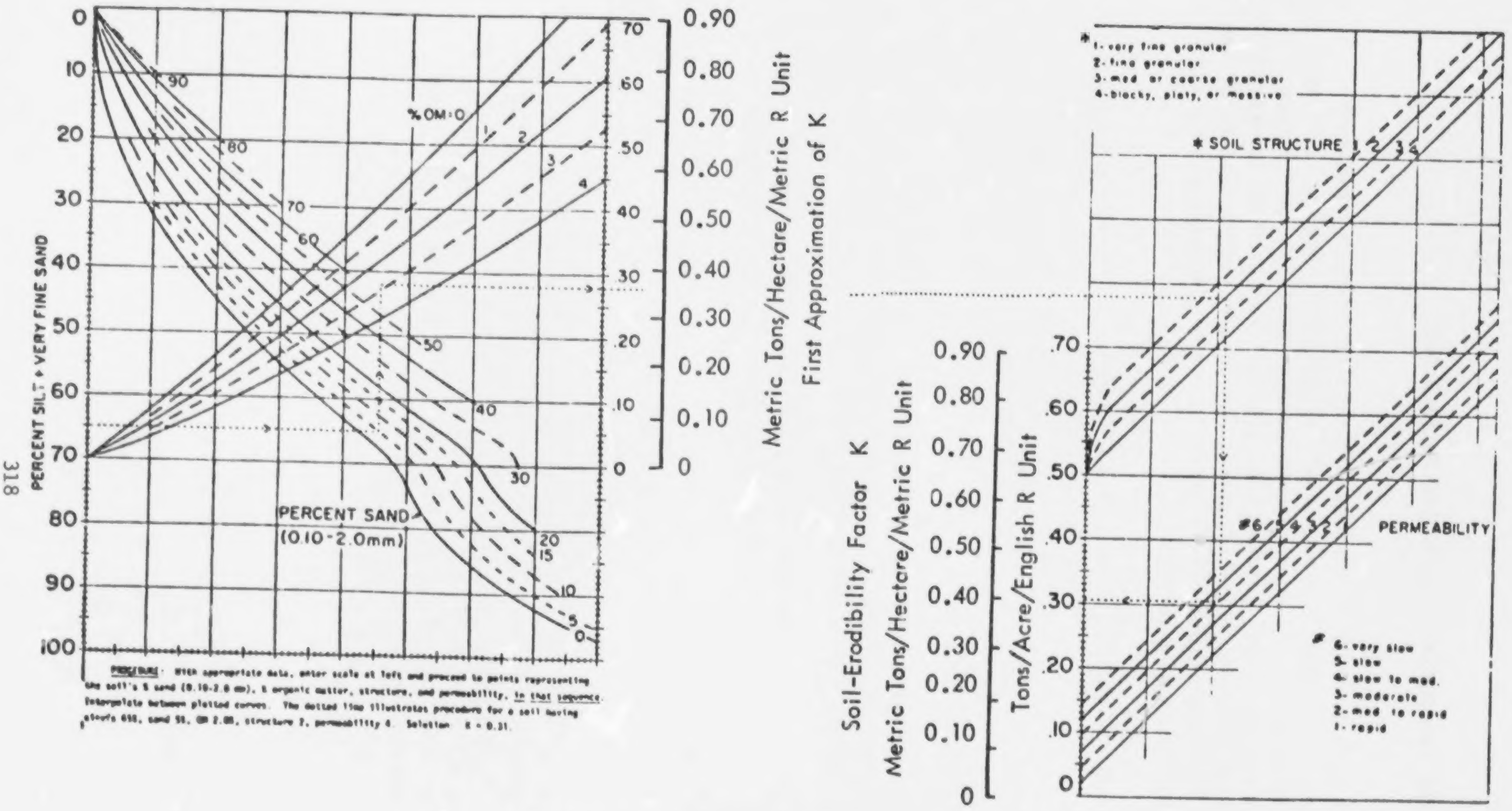

Figure B-1. Soil erodibility nomograph[a]

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[a] Wischmeier, W. H., C. B. Johnson, and B. U. Cross, "A Soil Erodibility Nomograph for Farmland and Construction Sites, J. Soil and Water Conservation, 26:189-193 (1971).

Organic matter

The percentage of organic matter was determined, in work by Wischmeier, et al., by the Walkley-Black method.[1] The organic matter content is approximately 1.72 times the percent carbon. Soil erodibility decreases as organic matter content increases.

Soil structure

The soil structure is descriptive of the overall arrangement of the soil solids. The four parameter values and their descriptions are as follows:

Parameter Value	Descriptions
	Granular - All rounded aggregates may be placed in this category. These rounded complexes usually lie loosely and are readily shaken apart. When wetted, the voids are not closed readily by swelling.
1	Very fine granular - less than 1 mm.
2	Fine granular - 1 to 2 mm.
3	Medium granular - 2 to 5 mm.
3	Coarse granular - 5 to 10 mm.
4	*Blocky* - Aggregates have been reduced to blocks, irregularly six-faced, and with their three dimensions more or less equal. In size, the fragments range from a fraction of an inch to 3 or 4 in. in thickness.
4	*Platy* - Aggregates are arranged in relatively thin plates or lenses.
4	*Prismatic* - Aggregates or pillars are vertically oriented, with tops plane, level, and clean cut. They commonly occur in subsoils of arid and semi-arid regions.
4	*Columnar* - Aggregates or pillars are vertically oriented, with rounded tops. They commonly occur when the soil profile is changing and the horizons are degrading.

---

[1] Walkley, A., and I. A. Black, "An Examination of the Degtjareff Method for Determining Soil Organic Matter," *Soil Sci.*, *37*, pp. 29-38 (1934).

4 *Massive* - Soil units are very large, irregular, featureless as far as characteristic aggregates are concerned.

Soil permeability

Soil permeability is that property of the soil that enables the soil to transmit water. Since different soil horizons vary in permeability, the relative permeability classes refer to the soil profile as a whole. The relative permeability classes are as follows:

Class	Permeability rates in in/hour	
1	Rapid	over 6.0
2	Moderately rapid	2.0 to 6.0
3	Moderate	0.6 to 2.0
4	Moderately slow	0.2 to 0.6
5	Slow	0.06 to 0.2
6	Very slow	less than 0.06

Reading the Nomograph

Entry values for all of the nomograph curves, except permeability class, are for the upper 6 or 7 in. of soil. For soils in cuts, the entry values are for the upper 6 or 7 in. of the newly exposed layer. In reading the nomograph, interpolate linearly between adjacent curves when the entry data do not coincide with the plotted curves of percent sand or percent organic matter. The percent of coarse fragments may be significant and is not included in the nomograph. Therefore, reduce the value of K read from the nomograph by 10% for soils with stratified subsoils that include layers of small stones or gravel without a seriously impeding layer above them.

Enter the left scale of the nomograph with the appropriate percent silt plus very fine sand, move horizontally to intersect the correct percent-sand curve (interpolating to the nearest percent), vertically to the correct organic matter curve, and then horizontally to the right scale for first approximation of soil erodibility.

For soils having a fine granular structure and moderate permeability, the value of K can be obtained directly from this scale. However, if the soil is other than of fine granular structure, or permeability is other than moderate, it is necessary to proceed to the second part of the nomograph, horizontally to intersect the correct structure curve, vertically downward to the permeability curve, and horizontally to the soil erodibility index scale.

NOMOGRAPH FOR PREDICTING K VALUES OF HIGH CLAY SUBSOILS

Subsoils are commonly heavier in texture than the surface soils. In addition, subsoils likely have aggregating agents that are very much different from those found in surface soils and the degree of aggregation is known to have a profound influence on erodibility.

From an EPA study[1] conducted at Purdue University, a multiple linear regression equation and nomograph were developed which can be used to estimate the erodibility factor, K, of many high clay soils. Multiple regression analysis revealed that amorphous iron, aluminum and silicon hydrous oxides serve as soil stabilizers in subsoils (whereas, organic matter is the major stabilizer in surface soils). The nomograph was developed from the multiple linear regression equation relating the erodibility factor to the soil texture factor, M, the amount of CDB (citrate-dithionite-bicarbonate) extractable iron and aluminum oxides, and the amount of CDB extractable silica oxide.

The equation used to derive the nomograph was:

$$K_{pred} = 0.32114 + 2.0167 \times 10^{-4} M - 0.14440 (\% Fe_2O_3 + \% Al_2O_3) - 0.83686 (\% SiO_2)$$

where K_{pred} = Predicted K value of subsoil

M = Soil texture factor, defined by percent new silt (percent new silt + percent new sand). "New" silt has 2 to 100 μm mean diameter. "New" sand has 100 to 2,000 μm mean diameter.

$\% Fe_2O_3$ = Percent CBD extractable iron oxide of soil.

$\% Al_2O_3$ = Percent CDB extractable aluminum oxide of soil.

$\% SiO_2$ = Percent CDB extractable silica oxide of soil.

---

[1] Roth, C. B., D. W. Nelson, and M. J. M. Romkens, "Prediction of Subsoil Erodibility Using Chemical, Mineralogical, and Physical Parameters," for the U.S. Environmental Protection Agency (EPA-660/2-74-043), Washington, D.C., June 1974.

The nomograph for estimating the erodibility factor, K, of high clay subsoils is reproduced in Figure B-2.

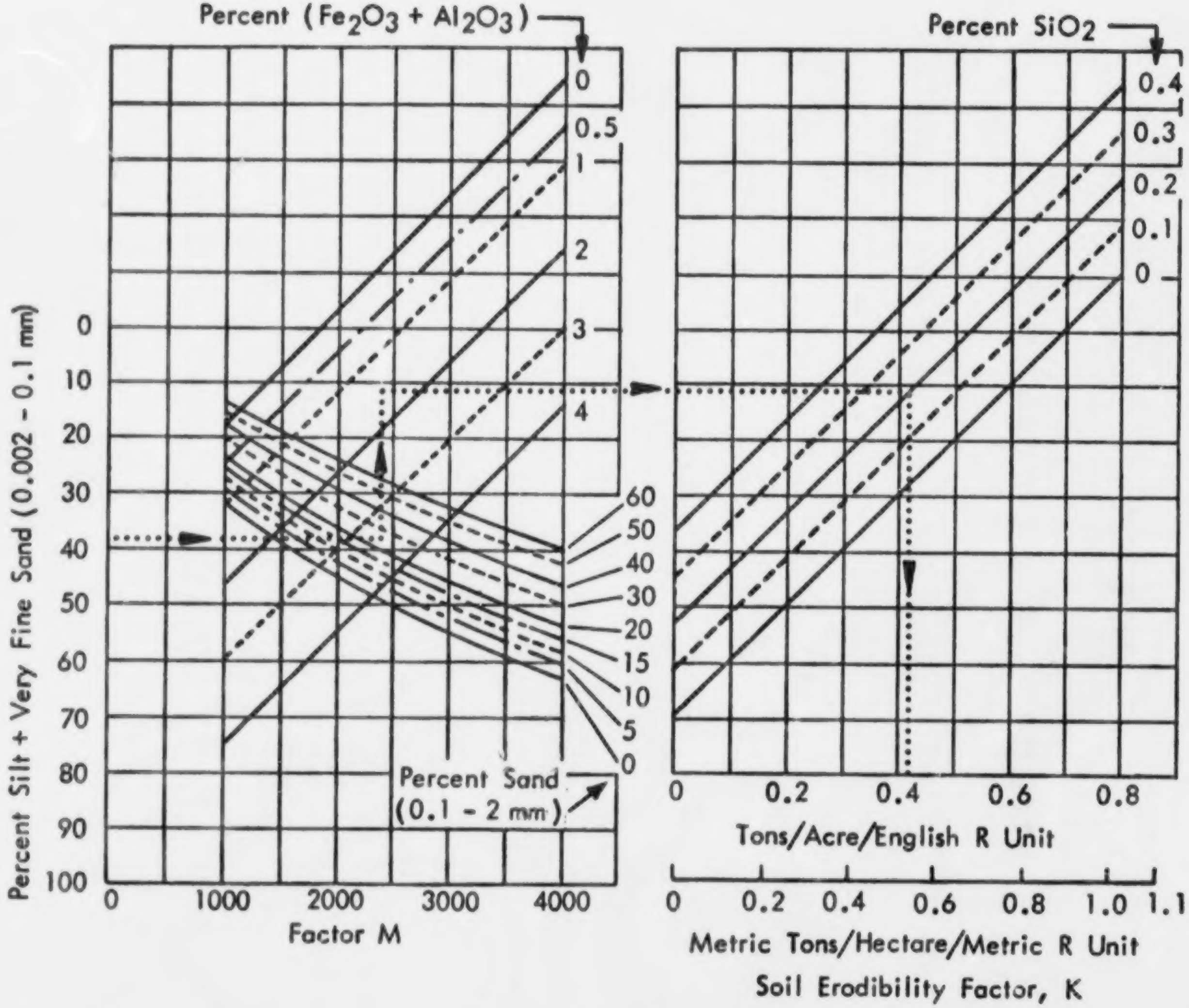


Figure B-2. Nomograph for estimating the erodibility factor K of high clay subsoils[a/]

[a/] Roth, C. B., D. W. Nelson, and M. J. M. Romkens, "Prediction of Subsoil Erodibility Using Chemical, Mineralogical, and Physical Parameters," for the U.S. Environmental Protection Agency (EPA-660/2-74-043), Washington, D.C., June 1974.

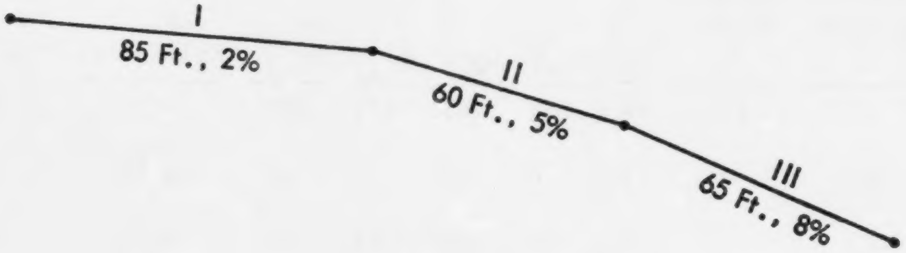
APPENDIX C

TOPOGRAPHIC FACTOR LS FOR IRREGULAR SLOPES

This appendix presents examples of calculating LS values for irregular slopes, one of convex slope and the other concave slope.

EXAMPLE 1--CONVEX SLOPE

The slope is shown below with values of slope length and slope percent indicated on each of the three segments.



Segment I

Enter the slope effect chart in Figure 4-8 at 85' (λ_1) on the horizontal scale, move upward to the curve for 2% slope, and read $U_{2,I} = 17$.

The upper end of Segment I is at zero length, therefore $\lambda_0 = 0$ and $U_{1,I} = 0$.

$U_{2,I} - U_{1,I} = 17$

Segment II

$\lambda_2 = 85' + 60' = 145'$
$\lambda_1 = 85'$

Enter the slope effect chart with lengths of 145' and 85', use the curve for 5%. Obtain $U_{2,II} = 91$ and $U_{1,II} = 41$. Thus

$U_{2,II} - U_{1,II} = 91 - 41 = 50$.

Segment III

$\lambda_3 = 85' + 60' + 65' = 210'$
$\lambda_2 = 85' + 60' = 145'$

Enter the slope chart with lengths of 210' and 145', use 8% curve, obtain $U_{2,III} = 310$ and $U_{1,III} = 170$.

$$U_{2,III} - U_{1,III} = 310 - 170 = 140$$

The computation is summarized below. The effective topographic factor LM is estimated at 0.99 for the entire slope.

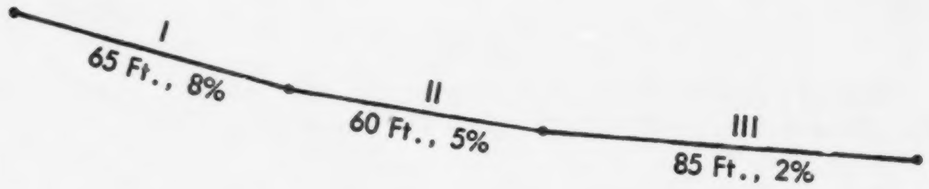
Segment, j (1)	Segment Length, ft (2)	Segment Slope, % (3)	λ_j (4)	λ_{j-1} (5)	$U_{2,j}$ (6)	$U_{1,j}$ (7)	$U_{2,j} - U_{1,j}$ (8)	Segment LS, Col(8)÷(2) (9)	cent of Total Yield* (10)
I	85	2	85	0	17	0	17	0.20	8
II	60	5	145	85	91	41	50	0.83	24
III	65	8	210	145	310	170	140	2.15	68
Entire Slope	210						207	0.99	100

---

* Assume constant soil erodibility for the entire slope, computed by dividing Col. (8) by 207, i.e., $[\Sigma(U_{2,j} - U_{1,j})]$.

EXAMPLE 2--CONCAVE SLOPE

A concave slope consists of three segments with values of slope length (feet) and slope gradient (%) shown in the graph below:



Segment I

$\lambda_1 = 65'$

$\lambda_0 = 0$

Use curve for 8% in Figure 4-8. Obtain

$U_{2,I} = 52$
$U_{1,I} = 0$

Segment II

$\lambda_2 = 65' + 60' = 125'$
$\lambda_1 = 65'$

Use 5% curve, obtain

$U_{2,II} = 68$
$U_{1,II} = 27$

Segment III

$\lambda_3 = 65' + 60' + 85' = 210'$
$\lambda_2 = 65' + 60' = 125'$

Use 2% curve, obtain

$U_{2,III} = 62$
$U_{1,III} = 32$

Computations are summarized in the following table. The effective LS value for the entire slope is estimated at 0.59.

Segment j (1)	Segment Length, ft (2)	Segment Slope % (3)	λ_j (4)	λ_{j-1} (5)	$U_{2,j}$ (6)	$U_{1,j}$ (7)	$U_{2,j}-U_{1,j}$ Col.(6)-Col.(7) (8)	Segment LS Col.(8)÷Col.(2) (9)	Percent of Total Yield (10)
I	65	8	65	0	52	0	52	0.84	42
II	60	5	125	65	68	27	41	0.68	33
III	85	2	210	125	62	32	30	0.35	25
Entire Slope	210						123	0.59	100

APPENDIX D

K · LS INDEXES FOR LAND RESOURCE AREAS EAST OF THE CONTINENTAL DIVIDE*

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* Calculated from results of 1972 SCS questionnaire survey.

K·LS INDEX -- metric tons per hectare per unit of erosion index, R
(tons per acre per unit of erosion index, R)

LAND CLASS and SUBCLASS	LAND RESOURCE AREA					
	32	33	42	46	50/51	52
I				0.14 (0.06)		0.13 (0.06)
IIe	0.27 (0.12)		0.38 (0.17)	0.41 (0.19)	0.22 (0.10)	0.74 (0.33)
IIs	0.14 (0.06)			0.14 (0.06)	0.31 (0.14)	0.25 (0.11)
IIw				0.14 (0.06)	0.19 (0.08)	0.25 (0.11)
IIc	0.31 (0.14)			0.18 (0.08)		0.22 (0.10)
IIIe	0.49 (0.22)	0.45 (0.20)		0.94 (0.42)		0.33 (0.15)
IIIs	0.09 (0.04)		0.29 (0.13)	0.22 (0.10)	0.27 (0.12)	
IIIw	0.31 (0.14)	0.13 (0.06)		0.26 (0.12)	0.43 (0.19)	
IIIc		0.25 (0.11)		0.18 (0.08)		0.25 (0.11)
IVe	0.40 (0.18)	0.94 (0.42)	0.11 (0.05)	2.2 (0.99)		1.0 (0.45)
IVs				0.18 (0.08)	0.23 (0.10)	0.22 (0.10)
IVw	0.25 (0.11)	0.13 (0.06)		0.18 (0.08)		
IVc				0.58 (0.26)	0.27 (0.12)	
Ve						
Vs	0.04 (0.02)			0.22 (0.10)	0.19 (0.09)	
Vw						
Vc						
VIe	1.19 (0.53)	4.9 (2.2)		3.6 (1.6)	4.5 (2.0)	3.4 (1.5)
VIs	0.07 (0.03)	5.2 (2.3)	0.18 (0.08)	2.8 (1.2)	4.3 (1.9)	0.22 (0.10)
VIw	0.25 (0.11)	0.25 (0.11)				0.25 (0.11)
VIc	0.43 (0.19)	0.49 (0.22)		0.29 (0.13)	0.54 (0.24)	
VIIe	4.3 (1.9)	2.9 (1.3)	0.16 (0.07)		0.63 (0.28)	9.3 (4.1)
VIIs		7.8 (3.5)	1.0 (0.45)	9.3 (2.4)		0.19 (0.09)
VIIw	0.29 (0.13)					
VIIc			0.74 (0.33)			
VIIIe	0.76 (0.34)	15.0 (6.7)		8.1 (3.6)		
VIIIs				9.5 (4.2)	22.0 (10.0)	6.5 (2.9)
VIIIw						
VIIIc						

K·LS INDEX -- metric tons per hectare per unit of erosion index, R
(tons per acre per unit of erosion index, R)

LAND CLASS and SUBCLASS	LAND RESOURCE AREA					
	53	54	55	56	57	58
I	0.19 (0.08)	0.18 (0.08)			0.22 (0.10)	0.13 (0.06)
IIe	0.58 (0.26)	0.65 (0.29)	0.22 (0.10)	1.2 (0.10)	0.43 (0.19)	0.25 (0.11)
IIs	0.58 (0.26)	0.49 (0.22)	0.38 (0.17)	0.43 (0.19)	0.13 (0.06)	0.13 (0.06)
IIw				0.29 (0.13)		
IIc	0.36 (0.16)	0.43 (0.19)	0.22 (0.10)	0.25 (0.11)	0.13 (0.06)	0.43 (0.19)
IIIe	1.1 (0.48)	1.1 (0.48)	1.1 (0.48)	0.18 (0.08)	1.2 (0.54)	0.76 (0.34)
IIIs	0.22 (0.10)	1.1 (0.49)	0.25 (0.11)	0.25 (0.11)	0.11 (0.05)	0.13 (0.06)
IIIw						0.49 (0.22)
IIIc						0.11 (0.05)
IVe	2.1 (0.93)	0.90 (0.40)	2.1 (0.93)	0.11 (0.05)	3.2 (1.4)	0.99 (0.44)
IVs	0.29 (0.13)	0.67 (0.30)	0.38 (0.17)	0.22 (0.10)	0.76 (0.34)	0.34 (0.15)
IVw						
IVc						0.25 (0.11)
Ve						
Vs						
Vw						
Vc						
VIe	1.6 (0.70)	2.4 (1.07)	1.6 (0.70)	0.27 (0.12)	5.4 (2.4)	2.3 (1.0)
VIs		1.1 (0.49)	0.13 (0.06)	0.09 (0.04)	0.76 (0.34)	0.22 (0.10)
VIw	1.4 (0.62)					0.25 (0.11)
VIc						0.43 (0.19)
VIIe		4.2 (1.89)	0.34 (0.15)	0.34 (0.15)	6.9 (3.1)	7.1 (3.2)
VIIs	0.58 (0.26)	1.1 (0.51)	1.0 (0.45)	0.22 (0.10)	3.1 (1.4)	0.29 (0.13)
VIIw						
VIIc						
VIIIe						8.6 (3.8)
VIIIs						6.5 (2.9)
VIIIw						
VIIIc						

K·LS INDEX -- metric tons per hectare per unit of erosion index, R
(tons per acre per unit of erosion index, R)

LAND CLASS and SUBCLASS	LAND RESOURCE AREA					
	59	60	61	62	63	64
I	0.13 (0.06)	0.13 (0.06)	0.18 (0.08)			0.13 (0.06)
IIe	0.34 (0.15)	0.13 (0.06)		0.43 (0.19)	0.49 (0.22)	0.22 (0.10)
IIs	0.16 (0.07)	0.16 (0.07)	0.25 (0.11)		0.09 (0.04)	0.11 (0.05)
IIw						
IIc	0.13 (0.06)		0.25 (0.11)	0.29 (0.13)	0.14 (0.06)	0.11 (0.05)
IIIe	1.1 (0.51)	0.72 (0.32)	0.43 (0.19)	0.85 (0.38)	0.99 (0.44)	0.43 (0.19)
IIIs	0.22 (0.10)	0.43 (0.19)	0.45 (0.20)		0.22 (0.10)	0.13 (0.06)
IIIw	0.13 (0.06)					
IIIc	0.13 (0.06)	0.29 (0.13)	0.25 (0.11)	0.43 (0.19)		
IVe	0.99 (0.44)	0.99 (0.44)	0.99 (0.44)	1.6 (0.70)	1.3 (0.59)	1.1 (0.48)
IVs	0.85 (0.38)	0.45 (0.20)	0.45 (0.20)		0.20 (0.09)	0.22 (0.10)
IVw						
IVc		0.27 (0.12)				
Ve						
Vs						
Vw	0.13 (0.06)					
Vc						
VIe	3.7 (1.7)	4.4 (1.96)	4.6 (2.1)	3.7 (1.6)	3.0 (1.3)	1.2 (0.54)
VIs	0.16 (0.07)	0.99 (0.44)	2.8 (1.3)		3.3 (1.5)	2.2 (0.96)
VIw	0.13 (0.06)					
VIc						
VIIe	17.0 (7.7)	110. (49.0)	6.6 (2.9)	6.9 (3.1)	8.8 (3.9)	10.0 (4.5)
VIIs	8.2 (3.6)	8.8 (3.9)			8.8 (3.9)	16.0 (7.0)
VIIw						
VIIc						
VIIIe			12.0 (5.5)			
VIIIs	6.5 (2.9)					13.0 (6.0)
VIIIw						
VIIIc						

K·LS INDEX -- metric tons per hectare per unit of erosion index, R
(tons per acre per unit of erosion index, R)

LAND CLASS and SUBCLASS	LAND RESOURCE AREA 65	66	67	70	71	72
I			0.22 (0.10)	0.16 (0.07)	0.13 (0.06)	0.22 (0.10)
IIe	0.09 (0.04)	0.43 (0.19)	0.49 (0.22)	0.16 (0.07)	0.29 (0.13)	0.36 (0.16)
IIs			0.13 (0.06)	0.18 (0.08)	0.20 (0.09)	0.29 (0.13)
IIw			0.22 (0.10)			
IIc	0.13 (0.06)	0.22 (0.10)	0.22 (0.10)		0.13 (0.06)	0.22 (0.10)
IIIe	0.18 (0.08)	0.27 (0.12)	0.25 (0.11)	0.31 (0.14)	1.3 (0.56)	0.35 (0.16)
IIIs			0.18 (0.08)	0.34 (0.15)	0.2 (0.09)	0.29 (0.13)
IIIw			0.16 (0.07)			
IIIc			0.25 (0.11)	0.31 (0.14)		0.25 (0.11)
IVe	0.11 (0.05)	0.81 (0.36)	0.07 (0.03)	0.65 (0.29)	1.4 (0.64)	0.58 (0.26)
IVs		0.20 (0.09)	0.34 (0.15)	0.18 (0.08)		
IVw			0.11 (0.05)	0.16 (0.07)		
IVc			0.11 (0.05)	0.31 (0.14)		
Ve						
Vs						
Vw			0.11 (0.05)	0.27 (0.12)		
Vc						
VIe	0.92 (0.41)	1.6 (0.72)	2.2 (0.96)	0.65 (0.29)	7.6 (3.4)	1.7 (0.77)
VIs	0.09 (0.04)	0.34 (0.15)	0.11 (0.05)	0.22 (0.10)	0.09 (0.04)	
VIw			0.07 (0.03)	0.18 (0.08)		
VIc				0.58 (0.26)		
VIIe	3.6 (1.6)	3.1 (1.4)	2.3 (1.0)	12. (5.3)	13. (5.8)	2.2 (1.0)
VIIs	3.6 (1.6)	0.60 (0.27)	0.43 (0.19)	1.5 (0.67)	2.4 (1.1)	3.7 (1.7)
VIIw			0.07 (0.03)			
VIIc						
VIIIe			9.4 (4.2)			
VIIIs				0.13 (0.06)		
VIIIw						
VIIIc						

K·LS INDEX -- metric tons per hectare per unit of erosion index, R
(tons per acre per unit of erosion index, R)

LAND CLASS and SUBCLASS	LAND RESOURCE AREA 73	74	75 (Nebr.)	75 (Kans.)	76	77
I			0.16 (0.07)			0.07 (0.03)
IIe	0.43 (0.19)	0.49 (0.22)	0.34 (0.15)	0.43 (0.19)	0.43 (0.19)	0.07 (0.03)
IIs	0.29 (0.13)	0.29 (0.13)	0.29 (0.13)	0.29 (0.13)	0.29 (0.13)	0.09 (0.04)
IIw						
IIc	0.25 (0.11)	0.25 (0.11)	0.16 (0.07)	0.25 (0.11)		
IIIe		0.78 (0.35)	0.58 (0.26)	0.49 (0.22)	0.49 (0.22)	0.43 (0.19)
IIIs			0.20 (0.09)			
IIIw						
IIIc						0.43 (0.19)
IVe		0.78 (0.35)	1.7 (0.74)	1.1 (0.47)	0.56 (0.25)	0.13 (0.06)
IVs		0.22 (0.10)		0.22 (0.10)	0.34 (0.15)	0.22 (0.10)
IVw						
IVc						0.43 (0.19)
Ve						
Vs						
Vw						0.04 (0.02)
Vc						
VIe	1.7 (0.77)	1.5 (0.67)	3.3 (1.5)	4.2 (1.9)	1.7 (0.77)	0.18 (0.08)
VIs			3.3 (1.5)			0.45 (0.20)
VIw						0.07 (0.03)
VIc						0.76 (0.34)
VIIe			13.0 (5.8)	2.2 (1.0)		0.04 (0.02)
VIIs	4.2 (1.9)		13.0 (5.8)	0.78 (0.35)	0.78 (0.35)	0.56 (0.25)
VIIw						
VIIc						
VIIIe						0.04 (0.02)
VIIIs			4.9 (2.2)			
VIIIw						
VIIIc						

K·LS INDEX -- metric tons per hectare per unit of erosion index, R
(tons per acre per unit of erosion index, R)

LAND CLASS and SUBCLASS	LAND RESOURCE AREA					
	78	79	80	81	82	83
I	0.18 (0.08)		0.18 (0.08)			0.04 (0.02)
IIe	0.43 (0.19)	0.18 (0.08)	0.49 (0.22)	0.29 (0.13)	0.31 (0.14)	0.22 (0.10)
IIs	0.29 (0.13)	0.29 (0.13)	0.29 (0.13)	0.07 (0.03)		0.07 (0.03)
IIw		0.09 (0.04)	0.22 (0.10)			0.07 (0.03)
IIc	0.22 (0.10)	0.25 (0.11)		0.07 (0.03)	0.04 (0.02)	0.07 (0.03)
IIIe	0.65 (0.29)	0.20 (0.09)	0.49 (0.22)	0.36 (0.16)	0.43 (0.19)	0.76 (0.34)
IIIs	0.29 (0.13)			0.07 (0.03)		0.09 (0.04)
IIIw				0.07 (0.03)		0.09 (0.04)
IIIc				0.31 (0.14)		0.11 (0.05)
IVe		0.45 (0.20)	0.67 (0.30)	0.43 (0.19)	0.31 (0.14)	0.25 (0.11)
IVs	0.22 (0.10)	0.22 (0.10)	0.38 (0.17)	0.07 (0.03)		0.07 (0.03)
IVw	0.31 (0.14)		0.25 (0.11)			0.09 (0.04)
IVc				0.07 (0.03)		0.07 (0.03)
Ve						
Vs			0.22 (0.10)			
Vw			0.22 (0.10)	0.07 (0.03)		0.07 (0.03)
Vc						
VIe	1.7 (0.74)	0.72 (0.32)	1.7 (0.74)	0.36 (0.16)		0.43 (0.19)
VIs	1.7 (0.74)		0.72 (0.32)	0.65 (0.29)	0.90 (0.14)	
VIw				0.04 (0.02)		0.04 (0.02)
VIc						0.49 (0.22)
VIIe	0.83 (0.37)	1.9 (0.87)	0.83 (0.37)			0.34 (0.15)
VIIs	1.0 (0.45)		0.11 (0.05)	2.9 (1.3)	1.3 (0.68)	0.81 (0.36)
VIIw						
VIIc						
VIIIe	0.54 (0.24)					
VIIIs			1.6 (0.72)			
VIIIw						
VIIIc						

K·LS INDEX -- metric tons per hectare per unit of erosion index, R
(tons per acre per unit of erosion index, R)

LAND CLASS and SUBCLASS	LAND RESOURCE AREA					
	84	85	86	87	88	90
I	0.22 (0.10)					0.16 (0.07)
IIe	0.27 (0.12)	0.43 (0.19)	0.22 (0.10)	0.38 (0.17)	0.49 (0.22)	0.67 (0.30)
IIs	0.29 (0.13)				0.19 (0.09)	0.25 (0.11)
IIw						0.49 (0.22)
IIc					0.25 (0.11)	
IIIe	0.38 (0.17)	0.58 (0.26)	0.65 (0.29)	0.67 (0.30)	1.4 (0.63)	1.4 (0.63)
IIIs					0.22 (0.10)	0.11 (0.05)
IIIw						0.29 (0.13)
IIIc					3.7 (1.7)	
IVe	0.65 (0.29)	1.0 (0.45)	1.2 (0.54)	0.67 (0.30)	0.31 (0.14)	2.6 (1.2)
IVs			0.29 (0.13)	0.45 (0.20)		0.07 (0.03)
IVw						
IVc						
Ve						
Vs						0.13 (0.06)
Vw	0.22 (0.10)					
Vc						
VIe	1.3 (0.58)	1.0 (0.45)	2.2 (0.96)	1.6 (0.73)	5.0 (2.2)	4.6 (2.1)
VIs	0.65 (0.29)	0.85 (0.38)			0.8 (0.34)	1.3 (0.59)
VIw						
VIc						
VIIe	0.83 (0.37)				8.0 (3.6)	4.0 (1.8)
VIIs	2.0 (0.89)	4.1 (1.8)			3.0 (1.4)	1.6 (0.70)
VIIw						
VIIc						
VIIIe						
VIIIs	0.29 (0.13)					
VIIIw						
VIIIc						

K·LS INDEX -- metric tons per hectare per unit of erosion index, R
(tons per acre per unit of erosion index, R)

LAND CLASS and SUBCLASS	LAND RESOURCE AREA 91	92 (Mich.)	92 (Wisc.)	93	94	95
I	0.16 (0.07)			0.13 (0.06)		0.13 (0.06)
IIe	0.67 (0.30)	0.58 (0.26)	0.67 (0.30)	0.58 (0.26)	0.31 (0.14)	0.67 (0.30)
IIs	0.13 (0.06)	0.13 (0.06)	0.13 (0.06)	0.18 (0.08)	0.20 (0.09)	0.16 (0.07)
IIw	0.25 (0.11)	0.38 (0.17)	0.16 (0.07)	0.29 (0.13)	0.16 (0.07)	
IIc						
IIIe	1.4 (0.63)	1.5 (0.65)	1.3 (0.60)	1.2 (0.54)	0.87 (0.39)	1.4 (0.63)
IIIs	0.27 (0.12)	0.31 (0.14)		0.11 (0.05)	0.27 (0.12)	0.43 (0.19)
IIIw	0.16 (0.07)	0.20 (0.09)	0.09 (0.04)			
IIIc						
IVe	0.85 (0.38)	3.1 (1.4)	3.6 (1.6)	3.2 (1.4)	2.0 (0.90)	3.4 (1.5)
IVs	0.11 (0.05)	0.38 (0.17)	0.27 (0.12)	0.07 (0.13)	0.27 (0.12)	0.27 (0.12)
IVw	0.07 (0.03)	0.27 (0.12)	0.13 (0.06)	0.07 (0.03)	0.07 (0.03)	
IVc						
Ve						
Vs	0.49 (0.22)					0.85 (0.38)
Vw	0.22 (0.10)					0.22 (0.10)
Vc						
VIe	2.2 (0.98)	4.6 (2.1)	7.1 (3.2)	6.0 (2.7)	2.9 (1.3)	2.6 (1.2)
VIs	0.65 (0.29)	0.20 (0.09)	0.54 (0.24)	0.65 (0.29)	0.27 (0.12)	2.5 (1.1)
VIw						
VIc						
VIIe	4.0 (1.8)	7.7 (3.4)	9.6 (4.3)	6.0 (2.7)	5.0 (2.2)	5.4 (2.4)
VIIs	1.6 (0.70)		1.4 (0.63)	1.7 (0.77)	2.2 (0.99)	0.27 (0.12)
VIIw						
VIIc						
VIIIe						
VIIIs						
VIIIw						
VIIIc						

K·LS INDEX -- metric tons per hectare per unit of erosion index, R
(tons per acre per unit of erosion index, R)

LAND CLASS and SUBCLASS	LAND RESOURCE AREA					
	96	97	98	99	100	101
I			0.16 (0.07)	0.16 (0.07)		
IIe	0.45 (0.20)	0.43 (0.19)	0.47 (0.21)	0.49 (0.22)	0.31 (0.14)	0.58 (0.26)
IIs	0.13 (0.06)	0.13 (0.06)	0.16 (0.07)	0.20 (0.09)	0.16 (0.07)	1.1 (0.49)
IIw		0.11 (0.05)	0.16 (0.07)			0.22 (0.10)
IIc						
IIIe	1.3 (0.59)	0.92 (0.41)	1.3 (0.56)	1.5 (0.69)	1.2 (0.52)	2.1 (0.93)
IIIs	0.31 (0.14)	0.38 (0.17)	0.31 (0.14)	0.11 (0.05)	0.31 (0.14)	0.20 (0.09)
IIIw						0.18 (0.08)
IIIc						
IVe	1.4 (0.62)	0.65 (0.29)	2.7 (1.2)	3.1 (1.4)	1.6 (0.73)	
IVs	0.27 (0.12)	0.27 (0.12)	2.5 (1.1)	0.27 (0.12)	0.20 (0.09)	0.65 (0.29)
IVw	0.07 (0.03)			0.07 (0.03)		0.34 (0.15)
IVc						
Ve						
Vs						0.13 (0.06)
Vw						
Vc						
VIe	2.6 (1.2)	1.7 (0.77)	2.2 (0.96)	2.5 (1.1)	6.2 (2.8)	6.9 (3.1)
VIs	0.65 (0.29)	0.58 (0.26)	0.25 (0.11)	0.27 (0.12)	1.6 (0.7)	0.25 (0.11)
VIw						
VIc						
VIIe	4.3 (1.9)	4.1 (1.8)	3.3 (1.5)	4.7 (2.1)	9.3 (4.1)	10.1 (4.5)
VIIs	1.9 (0.83)	0.45 (0.2)	0.99 (0.44)	0.65 (0.29)	8.8 (3.9)	0.65 (0.29
VIIw						
VIIc						
VIIIe						
VIIIs						
VIIIw						
VIIIc						

K·LS INDEX -- metric tons per hectare per unit of erosion index, R
(tons per acre per unit of erosion index, R)

LAND CLASS and SUBCLASS	LAND RESOURCE AREA 102	103	104	105	106	107
I	0.27 (0.12)	0.22 (0.10)	0.29 (0.13)	0.25 (0.11)	0.16 (0.07)	
IIe	0.65 (0.29)	0.43 (0.19)	0.49 (0.22)	0.67 (0.30)	0.43 (0.19)	0.36 (0.16)
IIs	0.18 (0.08)	0.13 (0.06)	0.13 (0.06)	0.18 (0.08)	0.20 (0.09)	0.22 (0.10)
IIw						
IIc						
IIIe	1.1 (0.51)	1.2 (0.54)	0.94 (0.42)	1.6 (0.70)	1.7 (0.74)	1.3 (0.58)
IIIs	0.45 (0.20)	0.11 (0.05)	0.27 (0.12)	0.11 (0.05)		0.11 (0.05)
IIIw			0.20 (0.09)	0.22 (0.10)		
IIIc						
IVe	1.7 (0.77)	3.7 (1.7)	2.9 (1.3)	3.7 (1.7)	1.9 (0.84)	3.6 (1.6)
IVs	0.38 (0.17)	0.27 (0.12)	0.2 (0.09)	0.27 (0.12)		
IVw	0.04 (0.02)					
IVc						
Ve						
Vs				0.09 (0.04)		
Vw						
Vc						
VIe	3.7 (1.6)	5.1 (2.3)	3.5 (1.6)	3.7 (1.7)	7.8 (3.5)	4.8 (2.2)
VIs	0.54 (0.24)	0.76 (0.34)	0.72 (0.32)	0.54 (0.24)	7.8 (3.5)	0.96 (0.43)
VIw						
VIc						
VIIe	4.2 (1.9)	9.9 (4.4)	5.1 (2.3)	5.2 (2.3)	12.9 (5.8)	15.0 (6.9)
VIIs	2.2 (0.96)	0.76 (0.34)	2.9 (1.3)	17.0 (7.8)	12.9 (5.8)	0.96 (0.43)
VIIw						
VIIc						
VIIIe						
VIIIs						
VIIIw						
VIIIc						

K·LS INDEX -- metric tons per hectare per unit of erosion index, R
(tons per acre per unit of erosion index, R)

LAND CLASS and SUBCLASS	LAND RESOURCE AREA					
	108	109	110	111	112	113
I				0.09 (0.04)		
IIe	0.43 (0.19)	0.43 (0.19)	0.43 (0.19)	0.43 (0.19)	0.36 (0.16)	0.25 (0.11)
IIs				0.09 (0.04)	0.29 (0.13)	
IIw				0.09 (0.04)		
IIc						
IIIe	1.2 (0.54)	1.4 (0.63)	0.87 (0.39)	1.2 (0.52)	0.92 (0.41)	0.92 (0.41)
IIIs			0.22 (0.10)	0.04 (0.02)		
IIIw						
IIIc						
IVe	1.7 (0.77)	1.4 (0.63)	4.1 (1.8)	3.1 (1.4)	0.92 (0.41)	1.5 (0.67)
IVs			0.16 (0.07)	0.27 (0.12)	0.34 (0.15)	
IVw						
IVc						
Ve						
Vs						
Vw						
Vc						
VIe	6.0 (2.7)	2.6 (1.2)	6.9 (3.1)	4.5 (2.0)	2.0 (0.89)	5.8 (2.6)
VIs		0.83 (0.37)	0.34 (0.15)	0.49 (0.22)		2.6 (1.2)
VIw						
VIc						
VIIe	1.7 (0.77)	6.0 (2.7)	7.9 (3.5)	13.0 (5.8)		11.7 (5.2)
VIIs	0.72 (0.32)	6.6 (2.9)	0.72 (0.32)	0.20 (0.09)	0.78 (0.35)	
VIIw						
VIIc						
VIIIe						
VIIIs						
VIIIw						
VIIIc						

K·LS INDEX -- metric tons per hectare per unit of erosion index, R
(tons per acre per unit of erosion index, R)

LAND CLASS and SUBCLASS	LAND RESOURCE AREA					
	114 (Ohio)	114 (Ill.)	115	116	117	118
I					0.15 (0.07)	0.16 (0.07)
IIe	0.43 (0.19)	0.58 (0.26)	0.36 (0.16)	0.43 (0.19)	0.22 (0.10)	0.27 (0.12)
IIs	0.34 (0.15)		0.22 (0.10)			
IIw						
IIc						
IIIe	1.4 (0.63)	1.1 (0.47)	1.2 (0.54)	0.43 (0.19)	0.76 (0.34)	0.92 (0.41)
IIIs						
IIIw					0.20 (0.09)	0.20 (0.09)
IIIc						
IVe	3.1 (1.4)		2.2 (0.96)	0.72 (0.32)	0.49 (0.22)	1.7 (0.76)
IVs		0.83 (0.37)	0.72 (0.32)	0.54 (0.24)		
IVw						
IVc						
Ve						
Vs						
Vw						
Vc						
VIe	6.0 (2.7)	6.1 (2.7)	2.6 (1.2)	4.3 (1.9)	5.3 (2.4)	3.0 (1.3)
VIs	3.1 (1.4)	2.5 (1.1)	1.8 (0.79)	1.8 (0.79)	1.1 (0.48)	1.1 (0.48)
VIw						
VIc						
VIIe	18.0 (7.8)	3.1 (1.4)	10.0 (4.6)	7.6 (3.4)	14.1 (6.3)	9.3 (4.1)
VIIs	21.0 (9.5)	4.6 (2.1)	6.6 (2.9)	2.7 (1.2)	14.1 (6.3)	9.3 (4.1)
VIIw						
VIIc						
VIIIe						
VIIIs						
VIIIw						
VIIIc						

K·LS INDEX -- metric tons per hectare per unit of erosion index, R
(tons per acre per unit of erosion index, R)

LAND CLASS and SUBCLASS	LAND RESOURCE AREA											
	125		126		127		128 (Va.)		128 (Ga.)		129	
I											0.07	(0.03)
IIe	0.45	(0.20)	0.72	(0.32)	0.69	(0.31)	0.65	(0.29)	0.29	(0.13)	0.38	(0.17)
IIs			0.18	(0.08)	0.18	(0.08)						
IIw									0.16	(0.07)	0.09	(0.04)
IIc												
IIIe	1.2	(0.53)	2.4	(1.1)	2.1	(0.95)	5.0	(2.2)	1.6	(0.70)	0.63	(0.28)
IIIs			0.31	(0.14)			0.49	(0.22)				
IIIw					0.87	(0.39)						
IIIc												
IVe	2.9	(1.3)	5.0	(2.2)	5.0	(2.2)	5.2	(2.3)	4.9	(2.2)	1.4	(0.62)
IVs	0.45	(0.20)	0.99	(0.44)	0.20	(0.09)	3.2	(1.4)	0.22	(0.10)		
IVw					0.87	(0.39)						
IVc												
Ve												
Vs					0.11	(0.05)						
Vw												
Vc												
VIe	6.1	(2.7)	10.0	(4.5)	8.2	(3.6)	11.5	(5.2)	7.7	(3.4)	2.6	(1.2)
VIs	6.0	(2.7)	2.1	(0.93)	1.2	(0.54)	5.7	(2.5)				
VIw									1.9	(0.86)		
VIc												
VIIe	8.9	(4.0)	18.2	(8.1)	10.8	(4.8)	18.2	(8.1)	4.9	(2.2)	2.6	(1.2)
VIIs	10.5	(4.7)	18.2	(8.1)	13.0	(6.0)	10.8	(4.8)	5.8	(2.6)	4.8	(2.1)
VIIw												
VIIc												
VIIIe												
VIIIs												
VIIIw												
VIIIc												

K·LS INDEX -- metric tons per hectare per unit of erosion index, R
(tons per acre per unit of erosion index, R)

LAND CLASS and SUBCLASS	LAND RESOURCE AREA 130	131	132	133 (N.C.)	133 (Ala.)	133 (La.)
I	0.18 (0.08)		0.25 (0.11)	0.18 (0.08)	0.13 (0.06)	
IIe	0.76 (0.34)	0.25 (0.11)	0.38 (0.17)	0.49 (0.22)	0.25 (0.11)	0.22 (0.10)
IIs				0.22 (0.10)	0.11 (0.05)	0.18 (0.08)
IIw				0.18 (0.08)		
IIc						
IIIe	1.0 (0.45)	0.22 (0.10)	0.96 (0.43)	0.76 (0.34)	0.56 (0.25)	0.34 (0.15)
IIIs				0.27 (0.12)	0.20 (0.09)	0.27 (0.12)
IIIw					0.13 (0.06)	
IIIc						
IVe	3.1 (1.4)		1.8 (0.82)	1.4 (0.62)	1.1 (0.48)	0.49 (0.22)
IVs				0.27 (0.12)	0.43 (0.19)	
IVw						
IVc						
Ve						
Vs						
Vw						
Vc						
VIe	6.5 (2.9)	4.1 (1.9)			1.7 (0.78)	3.09 (1.4)
VIs	0.81 (0.36)				0.65 (0.29)	
VIw						
VIc						
VIIe	6.5 (2.9)	8.0 (3.6)			4.9 (2.2)	
VIIs	9.9 (4.4)	7.0 (3.1)			2.2 (0.99)	
VIIw						
VIIc						
VIIIe						
VIIIs						0.49 (0.22)
VIIIw						
VIIIc						

K·LS INDEX -- metric tons per hectare per unit of erosion index, R
(tons per acre per unit of erosion index, R)

LAND CLASS and SUBCLASS	LAND RESOURCE AREA 135	136 (N.C.)	136 (Ga.)	137	138	139
I		0.09 (0.04)		0.13 (0.06)		
IIe	0.29 (0.13)	0.49 (0.22)	0.65 (0.29)	0.49 (0.22)	0.22 (0.10)	0.58 (0.26)
IIs	0.16 (0.07)		0.43 (0.19)	0.40 (0.18)	0.09 (0.04)	0.16 (0.07)
IIw				0.16 (0.07)	0.09 (0.04)	
IIc						
IIIe	0.43 (0.19)	1.14 (0.51)	0.65 (0.29)	0.92 (0.41)	0.25 (0.11)	1.1 (0.48)
IIIs	0.25 (0.11)	0.07 (0.03)	0.11 (0.05)	0.27 (0.12)	0.20 (0.09)	
IIIw						0.22 (0.10)
IIIc						
IVe	0.22 (0.10)	1.9 (0.83)	1.3 (0.58)	1.7 (0.78)	0.45 (0.20)	1.9 (0.83)
IVs	0.83 (0.37)			0.16 (0.07)	0.20 (0.09)	
IVw						
IVc						
Ve						
Vs						
Vw						
Vc						
VIe	1.2 (0.54)	4.1 (1.8)	2.4 (1.1)	3.4 (1.5)		5.1 (2.3)
VIs			1.2 (0.53)	1.0 (0.46)	0.83 (0.37)	
VIw						
VIc						
VIIe	5.0 (2.2)	6.3 (2.8)	4.9 (2.2)			7.0 (3.1)
VIIs			4.8 (2.2)	0.4 (0.18)	1.4 (0.61)	9.8 (4.4)
VIIw						
VIIc						
VIIIe						
VIIIs						
VIIIw						
VIIIc						

K·LS INDEX -- metric tons per hectare per unit of erosion index, R
(tons per acre per unit of erosion index, R)

LAND CLASS and SUBCLASS	LAND RESOURCE AREA 140	141	142	143	144	145
I						
IIe	0.40 (0.18)	0.43 (0.19)	0.76 (0.34)	0.40 (0.18)	0.31 (0.14)	0.58 (0.26)
IIs	0.13 (0.06)	0.16 (0.07)	0.16 (0.07)	0.38 (0.17)	0.22 (0.10)	0.20 (0.09)
IIw	0.13 (0.06)	0.16 (0.07)	0.22 (0.10)	0.38 (0.17)	0.38 (0.17)	0.31 (0.14)
IIc						
IIIe	1.7 (0.74)	1.1 (0.49)	2.4 (1.1)	0.85 (0.38)	1.2 (0.52)	1.3 (0.58)
IIIs	0.20 (0.09)	0.20 (0.09)	0.27 (0.12)	0.27 (0.12)	0.22 (0.10)	0.54 (0.24)
IIIw	0.54 (0.24)	0.40 (0.18)	0.45 (0.20)	0.11 (0.05)	0.13 (0.06)	0.13 (0.06)
IIIc						
IVe	2.9 (1.3)	2.4 (1.1)	5.6 (2.5)	2.2 (1.0)	4.2 (1.9)	0.43 (0.19)
IVs	1.4 (0.37)	0.83 (0.37)	0.83 (0.37)	0.72 (0.32)	0.83 (0.37)	0.38 (0.17)
IVw	0.22 (0.10)	0.25 (0.11)		0.25 (0.11)	0.45 (0.20)	
IVc						
Ve						
Vs	0.13 (0.06)				0.18 (0.08)	
Vw						
Vc						
VIe	4.3 (1.9)	5.2 (2.3)	6.0 (2.7)	3.4 (1.5)	2.6 (1.2)	1.8 (0.82)
VIs	1.9 (0.84)	0.56 (0.25)	0.81 (0.36)	0.85 (0.38)	0.83 (0.37)	0.92 (0.41)
VIw	1.6 (0.70)					
VIc						
VIIe	6.4 (2.8)	5.4 (2.4)		5.4 (2.4)	11.0 (4.7)	
VIIs	6.4 (2.8)	0.18 (0.08)	3.8 (1.7)	0.38 (0.17)	3.2 (1.4)	5.8 (2.6)
VIIw						
VIIc						
VIIIe						
VIIIs						5.8 (2.6)
VIIIw						
VIIIc						

K·LS INDEX -- metric tons per hectare per unit of erosion index, R
(tons per acre per unit of erosion index, R)

LAND CLASS and SUBCLASS	LAND RESOURCE AREA 146	147	148	149	150	151
I						
IIe	0.56 (0.25)	0.81 (0.36)	0.65 (0.29)	0.58 (0.26)	0.27 (0.12)	
IIs	0.38 (0.17)	0.22 (0.10)		0.27 (0.12)		
IIw	0.38 (0.17)			0.34 (0.15)		
IIc	0.25 (0.11)					
IIIe	0.85 (0.38)	1.9 (0.86)	1.6 (0.70)	1.1 (0.48)	0.38 (0.17)	0.38 (0.17)
IIIs	0.27 (0.12)	0.76 (0.34)		0.27 (0.12)	0.16 (0.07)	0.07 (0.03)
IIIw	0.38 (0.17)					
IIIc						
IVe	2.2 (1.0)	3.9 (1.7)	1.4 (0.61)	1.4 (0.62)	1.1 (0.48)	
IVs	0.72 (0.32)		0.83 (0.37)	0.22 (0.10)		
IVw	0.25 (0.11)	0.38 (0.17)		0.20 (0.09)		
IVc						
Ve						
Vs						
Vw						
Vc						
VIe	2.9 (1.3)	11.0 (5.0)	2.7 (1.2)	4.5 (2.0)	0.16 (0.07)	7.1 (3.2)
VIs	2.2 (1.0)	6.0 (2.7)	2.8 (1.3)			
VIw						
VIc						
VIIe		16.0 (7.2)	8.9 (4.0)	6.0 (2.7)		
VIIs	2.8 (1.2)	11.0 (5.1)	6.4 (2.9)	0.34 (0.15)		
VIIw						
VIIc						
VIIIe						
VIIIs						
VIIIw						
VIIIc						

K·LS INDEX -- metric tons per hectare per unit of erosion index, R
(tons per acre per unit of erosion index, R)

LAND CLASS and SUBCLASS	LAND RESOURCE AREA				
	152	153 (S.C.)	153 (N.C.)	154	155
I		0.13 (0.06)	0.18 (0.08)	0.04 (0.02)	
IIe	2.2 (0.98)	0.43 (0.19)	0.43 (0.19)	0.09 (0.04)	
IIs		0.31 (0.14)	0.83 (0.37)		
IIw	0.07 (0.03)		0.18 (0.08)	0.13 (0.06)	
IIc					
IIIe	2.5 (1.1)	1.3 (0.60)	1.5 (0.67)	0.34 (0.15)	
IIIs	0.20 (0.09)	0.27 (0.12)	0.31 (0.14)	0.34 (0.15)	0.27 (0.12)
IIIw					
IIIc					
IVe			1.5 (0.67)		
IVs	0.20 (0.09)	0.31 (0.14)	0.38 (0.17)	0.31 (0.14)	0.13 (0.06)
IVw					
IVc					
Ve					
Vs					
Vw					
Vc					
VIe					
VIs	0.04 (0.02)			0.45 (0.20)	
VIw					
VIc					
VIIe					
VIIs			2.0 (0.89)	1.7 (0.75)	0.07 (0.03)
VIIw					
VIIc					
VIIIe					
VIIIs			0.09 (0.04)		
VIIIw					
VIIIc					

APPENDIX E

ESTIMATED SOIL LOSSES FROM SELECTED CROPPING SYSTEMS IN AREAS WEST OF THE CONTINENTAL DIVIDE

From 1972 SCS Survey

STATE WASHINGTON

LRA 1

Form IW. Dominant Soil, L, S, and T Factors
and Estimated Tons Soil Lost to Erosion for
Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil	3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems					
					Pasture	Grass Clover Hay	Forest	Row Crop		
		(ft)	(%)	Tons per acre per year						
I	Cloquate sil, 0-3%	800	2	5	0	0	0	2		
IIe	Knappa sil, 2-5%	200	4	5	0.3	0.3	0.1	4		
IIs	Olequa sil, 0-3%	800	2	5	0	0	0	2		
IIw	Seattle muck	NA	0	5	0	NA	NA	1		
IIc	Knappa sil, 0-2%	400	1	5	0.1	0.1	0	1		
IIIe	Olympic sicl, 0-8%	800	4	4	0.2	0.2	0.1	NA		
IIIs	Queets sil, 0-5%	900	2	5	NA	NA	0	NA		
IIIw	Ginger cl, 0-4%	1000	1	5	0	0	0	NA		
IIIc	NA									
IVe	Boistfort cl, 3-25%	600	7	5	NA	NA	0.1	NA		
IVs	Cam sil, 0-3%	800	2	5	0.5	0.5	0	NA		
IVw	Ocosta sicl, diked	NA	0	5	0	0	0	NA		
IVc	NA									
Ve	NA									
Vw	Salzar sic	NA	0	5	0	0	0	NA		
Vs	Hoquiam sil, 0-3%	800	2	5	0.5	0.5	0	NA		
Vc	NA									
VIe	Copalis cl, 0-15%	1000	7	5	1	1	0.1	NA		
VIw	Yaquina ls	300	1		0.5	0.5	0	NA		
VIs	Sollecks channery sicl, 30-50%	800	35	2	NA	NA	0.2	NA		
VIc	NA									
VIIe	Lytell gr cl, 50-70%	800	55	3	NA	NA	0.4	NA		
VIIs	Dimal v channery sicl, 50-90%	700	70	1	NA	NA	0.6	NA		
VIIw	Alluvial land	30	1	2	NA	NA	0.1	NA		
VIIc	NA									
VIIIe	Dune land, 0-15% 1/	100	12	5	NA	NA	NA	NA		
VIIIs	Beach land & coastal beach 2/	200	2	0	NA	NA	NA	NA		
VIIIw	Riverwash 3/	100	4	0	NA	NA	NA	NA		
VIIIc	NA									

1/ Tons of soil loss is 1T. 2/ Tons of soil loss is 0.1T. 3/ Tons of soil loss is 50 T.

STATE OREGON

LRA 2

Form 1W. Dominant Soil, L, S, and T Factors and Estimated Tons Soil Lost to Erosion for Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil	3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems					
					Row Crop Cover Crop	Barley Rye Grass Seed	Wheat Clover	Orchard	Pasture and Grass Seed	Woodland
		(ft)	(%)		Tons per acre per year					
I	Chehalis sicl	500	1	5	1		1	1		
IIe	Salkum sicl, 2-6%	400	4	5	4		3	4	1	0.1
IIs	Salem grsil	600	1	3	1	1	1	1	1	
IIw	Woodburn sil, 0-3%	400	1	5	1		1	1	0.1	
IIc	None									
IIIe	Jory sicl, 7-12%	300	10	5	10	6	6	10	3	0.5
IIIs	Multnomah l, 0-3%	300	2	2			2	3	1	0.1
IIIw	Wapato sicl	NA	0	5		0	0		0	
IIIc	None									
IVe	Nekia sicl, 20-30%	500	25	2	20	10	10	20	4	1
IVs	None									
IVw	Dayton sil	NA	0	5		0			0	
IVc	NONE									
Ve	NONE									
Vw	NONE									
Vs	NONE									
Vc	NONE									
VIe	McCully cl, 30-50%	1200	40	5		15	15		5	1
VIw	Panther sicl, 4-20%	300	12	3					3	1
VIs	Klickitat stl, 3-30%	1200	15	3						1
VIc	None									
VIIe	Kinney kl, 50-70%	1200	60	3						1
VIIs	Klickitat vstl, 50-75%	1200	65	3						2
VIIw	NONE									
VIIc	NONE									
VIIIe	NONE									
VIIIs	Riverwash 1/	NA	0							
VIIIw	Tidal marsh (fresh water)	NA	0							
VIIIc	NONE									

1/ Tons of soil loss is 70T

STATE WASHINGTON

LRA 3

Form 1W. Dominant Soil, L, S, and T Factors and Estimated Tons Soil Lost to Erosion for Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil	3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems: Forest	Hay and Pasture	Row Crops			
		(ft)	(%)		Tons per acre per year					
I	NA									
IIe	Nekia c, 3-9%	500	5	2	0.1	.5	4.0			
IIs	NA									
IIw	Semiahmoo muck, 0-2%	800	1	5	0	NA	NA			
IIc	NA									
IIIe	Cinebar grsil, 8-15%	800	12	5	0	NA	NA			
IIIs	Puyallup fsl, 0-3%	350	2	5	0	.5	2.0			
IIIw	Bellingham sicl, 0-3%	800	1	5	0	NA	NA			
IIIc	NA									
IVe	Olympic sicl, 8-15%	1200	10	4	0.1	NA	NA			
IVs	Olympic stcl, 3-15%	1200	10	4	0.1	NA	NA			
IVw	Schooley sil, 0-3%	300	2	5	0	NA	NA			
IVc	NA									
Ve	NA									
Vw	NA									
Vs	NA									
Vc	NA									
VIe	Wilkeson l, 6-15%	1000	10	5	0.1	NA	NA			
VIw	Minniece sicl, 2-5%	300	2	5	0	NA	NA			
VIs	Klaus grsl, 8-15%	800	10	3	0	NA	NA			
VIc	NA									
VIIe	Rough mountainous land, 25-60%	1000	35	3	0.5	NA	NA			
VIIs	Cathcart cl, 3-15%	1000	8	3	0.1	NA	NA			
VIIw	NA									
VIIc	NA									
VIIIe	NA									
VIIIs	Lava flow	1200	8	0	NA	NA	NA			
VIIIw	Riverwash 1/	100	4	0	NA	NA	NA			
VIIIc	Snow and ice fields	1000	60	NA	NA	NA	NA			

1/ Tons of soil loss is 50 T.

STATE CALIFORNIA

LRA 4

Form 1W. Dominant Soil, L, S, and T Factors and Estimated Tons Soil Lost to Erosion for Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil	3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems: Irrigated Pasture		Timber not Grazed	Timber Grazed		
		(ft)	(%)	Tons per acre per year						
I	Ferndale sil, 0-2%	1200	1	5	.5					
IIe	Timmons 1, 2-5%	1200	3	5			.1	.3		
IIs	Corralitos sl, 0-2%	600	1	5	.25					
IIw	Rhonerville sl, slightly wet	450	1	3	.5					
IIc	NA									
IIIe	Josephine 1, 9-15%	400	10	3			.5	1.5		
IIIs	Arcata fsl, 0-2%	600	1	5	.5					
IIIw	Russ sil, slightly wet	1200	1	5	.25					
IIIc	NA									
IVe	Hugo 1, 15-30%	350	20	3			.75	2.0		
IVs	NA									
IVw	Coguille sicl	NA	0	5	.25					
IVc	NA									
Ve	NA									
Vw	NA									
Vs	NA									
Vc	NA									
VIe	Hugo 1, 30-50%	400	35	3			1.5	3.0		
VIw	Wet Alluvial Land	NA	0	5	.5					
VIs	NA									
VIc	NA									
VIIe	Hugo 1, 50-75%	350	55	3			2.0	3.5		
VIIs	NA									
VIIw	NA									
VIIc	NA									
VIIIe	Badland 1/	500	75	1						
VIIIs	Mayman 1, 50-75% 2/	300	60	1						
VIIIw	Riverwash 3/	1[illegible]00	2	5						
VIIIc	NA									

1/ Tons of soil loss is 75T.
2/ Tons of soil loss is 2T.
3/ Tons of soil loss is 50T.

STATE CALIFORNIA

LRA 5

Form 1W. Dominant Soil, L, S, and T Factors and Estimated Tons Soil Lost to Erosion for Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil	3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems				
					Irrigated Pasture			Woodland not grazed	Woodland Grazed
		(ft)	(%)		Tons per acre per year				
I	NA								
IIe	Ferndale sil, 2-9%	750	5	5				.25	.50
IIs	Arbuckle grl, 0-2%	1200	1	4	.75				
IIw	NA								
IIc	NA								
IIIe	Ettersburg grl, 2-9%	500	8	4				.5	1.5
IIIs	Columbia kfsl, 0-2%	600	1	5	.25				
IIIw	NA								
IIIc	NA								
IVe	Josephine l, 15-30%	350	25	3				.5	1.5
IVs	Neuns stl, 15-30%	400	25	3				.75	1.75
IVw	Red Bluff grl, wet, 0-5%	1200	3	2	1.25				
IVc	NA								
Ve	NA								
Vw	Chummy cl	NA	0	4	.25				
Vs	NA								
Vc	NA								
VIe	Hugo l, 30-50%	350	35	3				.5	2.0
VIw	NA								
VIs	Neuns stl, 30-50%	300	40	3				1.0	2.25
VIc	NA								
VIIe	Hugo stl, 50-75%	200	51	3				1.0	2.5
VIIs	Kinkel rol, 30-50%	350	35	3				1.0	2.0
VIIw	NA								
VIIc	NA								
VIIIe	NA								
VIIIs	Maymen l, 30-75% 1/	150	40	1					
VIIIw	Riverwash 2/	1200	2	5					
VIIIc	NA								

1/ Tons of soil loss is 2T.-
2/ Tons of soil loss is 50T.

STATE Washington

LRA 6

Form 1W. Dominant Soil L, S, and T Factors
and Estimated Tons Soil Lost to Erosion for
Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil	3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems					
					Forest	Hay and Pasture	Range Good	Range Poor		
		(ft)	(%)		Tons per acre per year					
I	NA									
IIe	Chemawa shotty 1, 2-5% (I)	500	2	5		.1				
IIs	Wenas 1, 0-2% (I)	200	1	5		.1				
IIw	NA									
IIc	Maupin 1 (I)	50	2	2		.2				
IIIe	McGowan 1, 3-8% (I)	1000	6	5	0.1	.3				
IIIs	Guler 1, 3-5% (I)	500	4	5	0.1	.2				
IIIw	Colville sil, 0-3% (I)	1000	2	5	0	.1				
IIIc	NA									
IVe	McGowan 1, 15-30%	800	20	5	0.2					
IVs	Yakima grsl, 0-2%	400	2	3			.1	1		
IVw	Chepaka sil, 0-3%	500	2	5	0		.1	1		
IVc	NA									
Ve	NA									
Vw	Chinchallo sil		0	5	0					
Vs	NA									
Vc	NA									
VIe	Underwood stl, 0-15%	500	12	3	0.1					
VIw	Bonneville cobbly sl, 3-8%	300	5	2	0.1	0.1				
VIs	Conconully vstfsl, 0-15%	600	10	5			.2	1.5		
VIc	NA									
VIIe	Rough Mountainous Land, 30-65%	1000	45	3	0.5					
VIIs	Pend Oreille stl, 0-8%	400	5	5	0.1					
VIIw	NA									
VIIc	NA									
VIIIe	NA									
VIIIs	Rock land, 30-100% 1/	800	60	0						
VIIIw	Riverwash 2/	100	4	0						
VIIIc	Snow and Ice Fields	1000	60							

1/ Tons of soil loss is 2T   2/ Tons of soil loss is 70T

STATE Washington

LRA 6

Form 1W. Dominant Soil, L, S, and T Factors
and Estimated Tons Soil Lost to Erosion for
Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil		3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems					
						Forest	Hay and Pasture	Range Good	Range Poor		
			(ft)	(%)		Tons per acre per year					
I	NA										
IIe	Chemawa shotty l, 2-5%	(I)	500	2	5		.1				
IIs	Wenas l, 0-2%	(I)	200	1	5		.1				
IIw	NA										
IIc	Maupin l	(I)	50	2	2		.2				
IIIc	McGowan l, 3-8%	(I)	1000	6	5	0.1	.3				
IIIs	Guler l, 3-5%	(I)	500	4	5	0.1	.2				
IIIw	Colville sil, 0-3%	(I)	1000	2	5	0	.1				
IIIc	NA										
IVe	McGowan l, 15-30%		800	20	5	0.2					
IVs	Yakima grsl, 0-2%		400	2	3			.1	1		
IVw	Chepaka sil, 0-3%		500	2	5	0		.1	1		
IVc	NA										
Ve	NA										
Vw	Chinchallo sil			0	5	0					
Vs	NA										
Vc	NA										
VIe	Underwood stl, 0-15%		500	12	3	0.1					
VIw	Bonneville cobbly sl, 3-8%		300	5	2	0.1	0.1				
VIs	Conconully vstfsl, 0-15%		600	10	5			.2	1.5		
VIc	NA										
VIIe	Rough Mountainous Land, 30-65%		1000	45	3	0.5					
VIIs	Pend Oreille stl, 0-8%		400	5	5	0.1					
VIIw	NA										
VIIc	NA										
VIIIe	NA										
VIIIs	Rock land, 30-100% 1/		800	60	0						
VIIIw	Riverwash 2/		100	4	0						
VIIIc	Snow and Ice Fields		1000	60							

1/ Tons of soil loss is 2T   2/ Tons of soil loss is 70T

STATE WASHINGTON

LRA 7

Form 1W. Dominant Soil, L, S, and T Factors and Estimated Tons Soil Lost to Erosion for Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil	3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems: Irrigated Row Crops	Irrigated Close-Grown Crops	Orchard Permanent Cover	Wheat 1yr. fallow	Rangeland Good Cover	Rangeland Poor Cover
		(ft)	(%)		Tons per acre per year					
I	Esquatzel sil, 0-2% (I)	1200	1	5	3	1	1			
IIe	Warden sil, 2-5% (I)	1200	4	5	6	3	1			
IIs	Naches 1, 0-2% (I)	1200	1	4	6	1	1			
IIw	Toppenish sil, 0-2% (I)	1200	.5	4	2	.5	.5			
IIc	NA									
IIIe	Ritzville sil, 5-30%	800	12	5				5	1	3
IIIs	Ashue 1, 0-2% (I)	1200	1	2	6	1	1			
IIIw	Pasco sil, 0-2% (I)	1200	.5	4	2	.5	.5			
IIIc	Ritzville sil, 0-5%	1200	3	5				2	1	2
IVe	Shano sil, 5-30%	800	12	5				4	1	3
IVs	White Sway sil, 2-5% (I)	500	4	2	6	3				
IVw	Fiander sil (I)	1200	.5	2	2	.5				
IVc	Warden sil, 0-5%	1200	4	5				1.5	1	2
Ve	NA									
Vw	NA									
Vs	NA									
Vc	NA									
VIe	Warden sil, sev. eroded, 15-30%	300	20	5				2		4
VIw	NA									
VIs	Cle Elum ksil, 0-3%	400	2	4					.5	1
VIc	NA									
VIIe	Quincy ls, 0-30%	300	10	5						3
VIIs	Lickskillet vstsil, 30-65%	300	45	2					1	3
VIIw	NA									
VIIc	NA									
VIIIe	Dune Land 1/	200	5	5						
VIIIs	Rock Outcrop	300	60	0						
VIIIw	Riverwash 2/	100	3	0						
VIIIc	NA									

1/ Tons of soil loss is 1T. 2/ Tons of soil loss is 80T.

STATE WASHINGTON

LRA 7

Form 1W. Dominant Soil, L, S, and T Factors
and Estimated Tons Soil Lost to Erosion for
Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil		3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems					
						Irrigated Row Crops	Irrigated Close-Grown Crops	Orchard Permanent Cover	Wheat 1yr. fallow	Rangeland Good Cover	Rangeland Poor Cover
			(ft)	(%)	Tons per acre per year						
I	Esquatzel sil, 0-2%	(I)	1200	1	5	3	1	1			
IIe	Warden sil, 2-5%	(I)	1200	4	5	6	3	1			
IIs	Naches l, 0-2%	(I)	1200	1	4	6	1	1			
IIw	Toppenish sil, 0-2%	(I)	1200	.5	4	2	.5	.5			
IIc	NA										
IIIe	Ritzville sil, 5-30%		800	12	5				5	1	3
IIIs	Ashue l, 0-2%	(I)	1200	1	2	6	1	1			
IIIw	Pasco sil, 0-2%	(I)	1200	.5	4	2	.5	.5			
IIIc	Ritzville sil, 0-5%		1200	3	5				2	1	2
IVe	Shano sil, 5-30%		800	12	5				4	1	3
IVs	White Sway sil, 2-5%	(I)	500	4	2	6	3				
IVw	Fiander sil	(I)	1200	.5	2	2	.5				
IVc	Warden sil, 0-5%		1200	4	5				1.5	1	2
Ve	NA										
Vw	NA										
Vs	NA										
Vc	NA										
VIe	Warden sil, sev. eroded, 15-30%		300	20	5				2		4
VIw	NA										
VIs	Cle Elum ksil, 0-3%		400	2	4					.5	1
VIc	NA										
VIIe	Quincy ls, 0-30%		300	10	5						3
VIIs	Lickskillet vstsil, 30-65%		300	45	2					1	3
VIIw	NA										
VIIc	NA										
VIIIe	Dune Land 1/		200	5	5						
VIIIs	Rock Outcrop		300	60	0						
VIIIw	Riverwash 2/		100	3	0						
VIIIc	NA										

1/ Tons of soil loss is 1T. 2/ Tons of soil loss is 80T.

STATE Oregon

LRA 8

Form 1W. Dominant Soil, L, S, and T Factors
and Estimated Tons Soil Lost to Erosion for
Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil	3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems				
					Wheat, fallow	Row crop, Grain, Hay	Hay Pasture	Range - Good	Range-Poor
		(ft)	(%)		Tons per acre per year				
I	Onyx sil (I)	600	1	5		2	1		
IIe	Walla Walla sil, 3-8% (I)	600	5	5		5	2		
IIs	Scooteney l, 0-2% (I)	400	1	2		2	1		
IIw	None								
IIc	Walla Walla sil, 0-8%	600	5	5	4			0.3	1
IIIe	Walla Walla sil, 8-30%	400	12	5	10			0.5	1.5
IIIs	Condon sil, 1-7%	800	3	2	5			0.3	1
IIIw	None								
IIIc	Ritzville sil, 0-8%	500	5	5	4			0.3	1
IVe	Shano sil, 5-30%	500	10	5	10			0.3	1
IVs	Scooteney kl, 0-5% (I)	300	3	2			1		
IVw	None								
IVc	None								
Ve	None								
Vw	None								
Vs	None								
Vc	None								
VIe	Walla Walla sil, 35-65%	500	50	5	50			0.5	1.5
VIw	None								
VIs	Stanfield sil, 0-6%	400	1	4				0	0
VIc	None								
VIIe	Quincy fs, 0-10%	300	3	5				0 3/	0 3/
VIIs	Lickskillet vstl, 7-40%	200	25	1				0.5	1.5
VIIw	None								
VIIc	None								
VIIIe	Duneland 1/	300	15	5				NA3/	NA3/
VIIIs	Riverwash 2/	NA	1						
VIIIw	None								
VIIIc	None								

1/ Tons of soil loss is 5T 2/ Tons of soil loss is 70T 3/ This does not show soil loss due to wind erosion which may be severe.

STATE WASHINGTON

LRA 9

Form 1W. Dominant Soil, L, S, and T Factors
and Estimated Tons Soil Lost to Erosion for
Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil	3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems					
					WHEAT Fallow	WHEAT, Peas or Lentils	WHEAT Contin.	WHEAT 4Yr. ALFALFA Grass 4Yr.	RANGELAND Cover GOOD	RANGELAND Cover POOR
		(ft)	(%)		Tons per acre per year					
I	NA									
IIe	Athena sil, 3-7%	400	5	5	4	3	2	1	.5	2
IIs	NA									
IIw	Caldwell sil	800	1	5	1	1	1	0.5	0	1
IIc	Mondovi sil	800	1	5	1	1	1	0.5	0	1
IIIe	Palouse sil, 7-25%	300	12	5	14	6	2	1.5	1	2
IIIs	Kaschmit sic, 0-7%	400	6	4	4	NA	NA	NA	1	2
IIIw	Latah sil	800	2	5	1	1	1	0.5	0	1
IIIc	NA									
IVe	Athena sil, 25-40%	300	30	5	25	11	6	4	1	3
IVs	NA									
IVw	NA									
IVc	NA									
Ve	NA									
Vw	Semiahmoo muck	1000	0.5	5	NA	NA	NA	NA	0	0
Vs	NA									
Vc	NA									
VIe	Athena sil, 40-55%	200	47	5	65	18	12	8	2	4
VIw	Emdent sil	1000	1	5	NA	NA	NA	NA	0	0.5
VIs	Hesselcine stsil, 0-20%	700	8	2	NA	NA	NA	NA	0.5	1.5
VIc	NA									
VIIe	Waha sil, 45-60¢	400	50	3	NA	NA	NA	NA	1	2
VIIs	Gwin rosil, 30-60%	400	45	1	NA	NA	NA	NA	1	2
VIIw	NA									
VIIc	NA									
VIIIe	Gwin stl, 50-80% 1/	100	60	1						
VIIIs	Rock outcrop	300	60	0						
VIIIw	Riverwash 2/	100	3	0						
VIIIc	NA									

1/ Tons of soil loss is 1T   2/ Tons of soil loss is 60T

STATE OREGON

LRA 10

Form 1W. Dominant Soil, L, S, and T Factors
and Estimated Tons Soil Lost to Erosion for
Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil		3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems				
						Row Crop Hay, and Grain	Hay, Pasture	Wheat: Fallow	Range GOOD	Range POOR
			(ft)	(%)		Tons per acre per year				
I	Powder sil	(I)	800	1	5	2	1			
IIe	Madras sl, 3-7%	(I)	500	5	2	4	1			
IIs	Deschutes sl, 6-30%	(I)	400	2	2	2	1			
IIw	Wingville sil	(I)	1000	1	5	2	1			
IIc	Newell l, 0-2%	(I)	500	1	5	3	1			
IIIe	Tub grcl, 1-12%		800	7	2			8	0.3	1
IIIs	Deskamp ls, 0-3%	(I)	400	2	2	2	1			
IIIw	Baldock sil	(I)	1200	1	5	2	1			
IIIc	None									
IVe	Ladd sil, 7-12%	(I)	500	10	5	8	3			
IVs	Halfway c		800	1	5		0.1			
IVw	Camascreek l		300	1	5				0	0
IVc	None									
Vc	None									
Vw	Camascreek l, very wet		NA	0	5				0	0
Vs	None									
Vc	None									
VIe	Simas ksicl, 10-35%		1200	25	2				0.5	1.5
VIw	None									
VIs	Gem stcl, 7-20%		200	10	2				0.3	1
VIc	None									
VIIe	Nagle sil, 35-65%		1200	50	3				0.5	1.5
VIIs	Simas vstcl, 35-70%		1200	60	2				0.5	1.5
VIIw	None									
VIIc	None									
VIIe	Badlands 1/		1200	50						
VIIs	Rockland 2/		400	15	1					
VIIIw	None									
VIIIc	None									

1/ Tons of soil loss is 50T

2/ Tons of soil loss is 1T

STATE Idaho

LRA 11

Form 1W. Dominant Soil, L, S, and T Factors and Estimated Tons Soil Lost to Erosion for Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil	3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems: Irrigated Row Crops	Irrigated Row Crops Grain&Hay	Irrig. Hay & Pasture	Rangeland; good cover	Rangeland Poor cover
		(ft)	(%)	Tons per acre per year					
I	Power sil, 0-2% (I)	1500	1	5	2	1	0	NA	NA
IIe	Portneuf sil, 2-4% (I)	900	3	5	7	6	1	NA	NA
IIs	Turbyfill sl, 0-2% (I)	600	1	5	4	3	0		
IIw	Draper l, 0-1% (I)	NA	0	5	0	0	0		
IIc	Portneuf sil, 0-2% (I)	1000	1	5	2	1	0		
IIIe	Minidoka sil, 4-8% (I)	200	6	2	7	6	1		
IIIs	Bannock l, 0-2% (I)	1000	1	2	2	1	0		
IIIw	Moulton fsl, 0-1% (I)	NA	0	3	0	0	0		
IIIc	Neeley sil, 0-4% (I)	300	2	5	3	2	1		
IVe	Pancheri sil, 8-12% (I)	200	10	5	15	11	3		
IVs	Wardboro grsl, 0-2% (I)	200	1	1		0	0		
IVw	Bramwell sil, mod sal, 0-2% (I)	200	1	5		0	0		
IVc	Pancheri sil, 0-2%	400	1	5				0	1
Ve	NA								
Vw	LaJara sl, 0-2%	NA	0	3				0	0
Vs	NA								
Vc	NA								
VIe	Minidoka sil, 0-30%	100	13	2				2	10
VIw	Baldock sil st sal-alk, 0-1%	NA	0	5				0	0
VIs	Trevino rosil, 4-8%	100	6	1				0	3
VIc	Matheson sl, 0-2%	200	1	4				0	1
VIIc	Quincy s, 0-30%	100	5	5				0(wind)	0(wind)
VIIs	Trevino vstsil, 0-30%	50	8	1				0	3
VIIw	Wardboro undifferentiated 0-1%	NA	0	1				0	0
VIIc	Turbyfill fsl, 0-2%	300	1	5				0	1
VIIIe	Gullied Land, undiff. 1/	20	30	1					
VIIIs	Rockland, undiff. 2/	50	15	1					
VIIIw	March, undiff. 3/	NA	0	1					
VIIIc	None								

1/ Tons of soil loss is 50T 2/ Tons of soil loss is 5T 3/ Tons of soil loss is 0T

STATE Idaho

LRA 12

Form 1W. Dominant Soil, L, S, and T Factors and Estimated Tons Soil Lost to Erosion for Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil	3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems					
					Irrigated Small grain hay&Pasture	Irrigated Hay & Pasture	Range-land good cover	Rangeland Poor cover		
		(ft)	(%)	Tons per acre per year						
I	NA									
IIe	NA									
IIs	NA									
IIw	NA									
IIc	NA									
IIIe	Berniceton 1, 2-4% (I)	600	3	4	2	1				
IIIs	Berniceton 1,mod deep,0-2%(I)	1000	1	3	1	0				
IIIw	Foxcreek 1, 0-2% (I)	200	1	3		0				
IIIc	Berniceton 1, 0-2% (I)	1000	1	4	1	0				
IVe	Pattoe sil, mod deep,8-12%(I)	200	10	3	3	1				
IVs	Bart 1, 0-2% (I)	600	1	3	1	0				
IVw	Furniss silcl,0-2% (I)	200	1	4		0				
IVc	NA									
Ve	NA									
Vw	Fury silcl (I)		0	5		0				
Vs	NA									
Vc	NA									
VIe	Bartonflat grl, 8-12%	100	10	1			1	5		
VIw	Borah grsl, flooded, 0-2%	100	1	1			0	2		
VIs	Bart 1, shallow 0-8%	200	4	2			0	3		
VIc	NA									
VIIe	Typic Argixerolls, stony	100	40	2			2	30		
VIIs	Xerollic Calciorthoids, cobbly	100	2	1			0	2		
VIIw	NA									
VIIc	NA									
VIIIe	NA									
VIIIs	Rockland 1/	100	60	1						
VIIIw	NA									
VIIIc	NA									

1/ Tons of soil loss is 20T.

STATE IDAHO

LRA 13

Form 1W. Dominant Soil, L, S, and T Factors and Estimated Tons Soil Lost to Erosion for Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil	3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems: Irrigated Grain Hay Pasture	Grain-fallow	Grain Alfalfa	Rangeland, Good Cover	Rangeland, Poor Cover
		(ft)	(%)		Tons per acre per year				
I	NA								
IIc	NA								
IIe	NA								
IIw	NA								
IIc	Blackfoot sil, drained, 0-2%(I)	600	1	5	1				
IIIe	Bancroft sil, 8-12%	300	7	5		7	5	0	3
IIIs	Driggs grl, 0-2% (I)	1000	1	3	1				
IIIw	Zufelt sil, drained, 2-4% (I)	300	3	3	1				
IIIc	Tetonia sil, 4-8%	400	5	5		5	3	0	2
IVe	Ririe sil, 4-12%	200	8	5		9	6	0	4
IVs	Bannock l, 0-4%	500	2	2		2	1	0	1
IVw	Bear Lake sicl, 0-2%	200	1	4		0		0	
IVc	Alex cl, deep 0-4%	200	2	4				0	1
Ve	NA								
Vw	Furnis cl	NA	0	4				0	
Vs	NA								
Vc	NA								
VIe	Sessions sil, 0-30%	200	12	4				1	5
VIw	NA 4-8%								
VIs	Eaglecone l - Rock outcrops	100	6	4				0	2
VIc	Enochville sil, drained, 0-2%	300	1	5				0	1
VIIe	Highams stsil, 30-60%	100	40	1				2	15
VIIs	Swanner vstl, 30-60%	100	40	1				1	6
VIIw	NA								
VIIc	NA								
VIIIe	NA								
VIIIs	Rockland 1/	50	15	1					
VIIIw	Marsh 2/	NA	0	5					
VIIIc	NA								

1/ Tons of soil loss is 5T

2/ Tons of soil loss is OT

STATE CALIFORNIA

LRA 14

Form 1W. Dominant Soil, L, S, and T Factors
and Estimated Tons Soil Lost to Erosion for
Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil		3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems					
						Irrig Row Crops	Irrig Field Crops	Irrig* Orchard	Irrig Pasture and Hay	Irrig Grain	Range Average
			(ft)	(%)		Tons per acre per year					
I	Sorrento cl, 0-2%	(I)	1200	1	5	0.5	0.5	0.5	0.5	--	--
IIe	Pajaro l, 2-9%	(I)	1000	2	5	--	0.5	--	0.5	0.5	--
IIs	Clear Lake, c, drained	(I)	NA	0	4	0.5	0.5	0.5	0.5	0.5	--
IIw	Pacheco sicl	(I)	NA	0	5	0.25	0.25	0.25	0.5	0.5	--
IIc	NA		--	--	--	--	--	--	--	--	--
IIIe	Antioch cl, 2-5%	(I)	750	3	2	0.5	0.5	NA	0.75	0.75	0.75
IIIs	Metz cls, 0-9%	(I)	1200	1	5	0.5	0.5	0.5	0.5	0.5	0.5
IIIw	Sunnyvale sicl	(I)	NA	0	3	0.25	0.25	0.5	0.25	0.5	--
IIIc	NA		--	--	--	--	--	--	--	--	--
IVe	Diablo c, 15-30%	(I)	650	20	3	--	0.75	1.0	0.75	1.0	1.5
IVs	Oceano s, 0-9%	(I)	900	7	5	1.0	1.0	1.0	1.25	--	2.0
IVw	Pescadero c	(I)	NA	0	5	0.25	0.25	--	0.5	0.5	0.75
IVc	NA		--	--	--	--	--	--	--	--	--
Ve	NA		--	--	--	--	--	--	--	--	--
Vw	NA		--	--	--	--	--	--	--	--	--
Vs	NA		--	--	--	--	--	--	--	--	--
Vc	NA		--	--	--	--	--	--	--	--	--
VIe	Tierra sl, 15-30%		600	20	2	--	--	--	--	--	2.0
VIw	NA		--	--	--	--	--	--	--	--	--
VIs	Baywood s, 15-30%		600	20	3	--	--	--	--	--	3.5
VIc	NA		--	--	--	--	--	--	--	--	--
VIIe	Chamise grl, 30-50%		400	35	2	--	--	--	--	--	2.0
VIIs	Antioch ls, 30-50%		450	35	3	--	--	--	--	--	3.0
VIIw	NA		--	--	--	--	--	--	--	--	--
VIIc	NA		--	--	--	--	--	--	--	--	--
VIIIe	Gullied land 1/		150	60	1	--	--	--	--	--	--
VIIIs	Maymen l, 50-85%		350	55	1	--	--	--	--	--	--
VIIIw	Alviso sic		NA	0	3	--	--	--	--	--	--
VIIIc	NA		--	--	--	--	--	--	--	--	--

1/ Tons of soil loss is 75T 2/ Tons of soil loss is 2T 3/ Tons of soil loss is 0 T

* Only shallow rooted or water tolerant trees, eg. Poor (?)

STATE California

LRA 15

(All Dryland)

Form 1W. Dominant Soil, L, S, and T Factors
and Estimated Tons Soil Lost to Erosion for
Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1.Capability Class and Subclass	2.Dominant Soil	3.Dom Slope Length	4.Dom % Slope	5.T Factor	6. Estimate Soil Losses for Selected Cropping Systems					
					Dryland Grain	Dryland Pastures	Range Good	Range Poor		
		(ft)	(%)	Tons per acre per year						
I	NA	NA	NA	NA	NA	NA	NA	NA		
IIe	NA									
IIs	NA									
IIw	NA									
IIc	NA									
IIIe	Linne sicl, 9-15%	800	12	3	0.75	1.25	0.75	1.5		
IIIs	Cajon fs, 0-2%	1200	1	5	0.75	1.0	0.75	1.5		
IIIw	Clear Lake c	NA	0	4	0.25	0.25	0.25	0.5		
IIIc	Agueda 1, 0-2%	1000	1	5	0.5	0.5	0.5	0.5		
IVe	Linne sicl, 15-30%	700	20	3	1.0	1.75	1.0	2.25		
IVs	Maxwell c	NA	0	4	0.25	0.5	0.25	0.5		
IVw	Pescadero c	NA	0	4	0.25	0.5	0.25	0.5		
IVc	Docas sil, 0-2%	1200	1	5	0.5	0.75	0.5	0.75		
Ve	NA									
Vw	NA									
Vs	NA									
Vc	NA									
VIe	Laughlin 1, 30-50%	600	40	2			1.75	3.25		
VIw	NA									
VIs	Arnold ls, 15-30%	500	20	4			2.0	3.75		
VIc	Panhill 1, 0-2%	1000	1	5			0.25	0.5		
VIIe	Vallecitos rol, 50-75%	500	50	2			1.75	3.50		
VIIs	Montara rosicl, 30-50%	500	40	1			1.75	3.25		
VIIw	Alluvial Land	800	2	5			0.5	0.75		
VIIc	NA									
VIIIe	Badlands 1/	250	75	1						
VIIIs	Maymen 1, 50-85% 2/	350	70	1						
VIIIw	Alviso sic 3/	NA	0	2						
VIIIc	NA									

1/ Tons of soil loss is 75T 2/ Tons of soil loss is 2T 3/ Tons of soil loss is 0T

STATE California

LRA 16

Form 1W. Dominant Soil, L, S, and T Factors
and Estimated Tons Soil Lost to Erosion for
Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1.Capability Class and Subclass	2.Dominant Soil	3.Dom Slope Length	4.Dom % Slope	5.T Factor	6. Estimate Soil Losses for Selected Cropping Systems				
					Irrigated Row Crops	Irrigated Pasture & Hay	Irrigated Field Crops		
		(ft)	(%)	Tons per acre per year					
I	NA								
IIe	NA								
IIs	NA								
IIw	Columbia l (I)	0	0	5	0.5	0.25	0.5		
IIc	NA								
IIIe	NA								
IIIs	NA								
IIIw	Ryde cl (I)	NA	0	5	0.5	0.25	0.5		
IIIc	NA								
IVe	Piper fsl (I)	NA	0	5	1.5	0.5	0.75		
IVs	NA								
IVw	Sacramento c (I)	NA	0	5	0.5	0.25	0.5		
IVc	NA								
Ve	NA								
Vw	NA								
Vs	NA								
Vc	NA								
VIe	NA								
VIw	Tamba mucky c (I)	NA	0	5	0.75	0.5	0.75		
VIs	NA								
VIc	NA								
VIIe	NA								
VIIs	NA								
VIIw	NA								
VIIc	NA								
VIIIe	NA								
VIIIs	NA								
VIIIw	Tidal marsh	NA	0	5					
VIIIc	NA								

STATE California

LRA 17

Form 1W. Dominant Soil, L, S, and T Factors and Estimated Tons Soil Lost to Erosion for Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil		3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems					
						Irrigated Row Crops	Irrigated Field Crops	Irrig. Pastures & Hay	Range Good	Range Poor	
			(ft)	(%)		Tons per acre per year					
I	Panoche 1, 0-2%	(I)	1200	1	5	0.5	0.5	0.5			
IIe	Snelling fsl, 2-9%	(I)	950	3	5	0.5	0.75	0.5			
IIs	Chino sil alkali, 0-2%	(I)	NA	0	4	0.5	0.5	0.5			
IIw	Columbia 1, wet	(I)	NA	0	5	0.5	0.5	0.5			
IIc	NA										
IIIe	Diablo c, 9-15%	(I)	850	12	3		0.75	1.0			
IIIs	Fresno 1	(I)	1200	0	3	0.5	0.5	0.5			
IIIw	Stockton c	(I)	1200	0	4	0.5	0.5	0.5			
IIIc	NA										
IVe	Redding grl, 2-5%	(I)	900	4	2			0.75			
IVs	San Joaquin sl,	(I)	NA	0	2	0.5	0.5	0.5			
IVw	Rossi cl	(I)	NA	0	5		0.5	0.5			
IVc	NA										
Ve	NA										
Vw	NA										
Vs	NA										
Vc	NA										
VIe	Kettleman 1, 15-30%		550	25	2				1.5	3.0	
VIw	Orland fsl, wet		900	0	5			0.75	0.75	2.0	
VIs	Auburn rol, 30-50%		425	35	1				1.75	3.0	
VIc	San Emigdio fsl, 0-2%		1200	1	5				1.0	2.5	
VIIe	Altamont c, 50-75%		400	55	2				1.75	3.5	
VIIs	Amador 1, 9-30%		600	10	1				1.0	2.25	
VIIw	Alluvial Land		1200	2	5				1.5	2.5	
VIIc	NA										
VIIIe	NA										
VIIIs	Tailings 1/		15	30	5						
VIIIw	Riverwash 2/		1200	2	5						
VIIIc	NA										

1/ Tons of soil loss is 1T

2/ Tons of soil loss is 50T

STATE CALIFORNIA

LRA 19

Form 1W. Dominant Soil, L, S, and T Factors and Estimated Tons Soil Lost to Erosion for Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil	3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems: Irrig. Row Crops	Irrig Field Crops	Citrus	Avocados	Irrig. Pasture & Hay	Range Average
		(ft)	(%)		Tons per acre per year					
I	Hanford fsl, 0-2% (I)	1200	1	5	0.25	0.25	0.25	0.25	0.25	
IIe	Hanford fsl, 2-9% (I)	800	5	5	0.5	0.5	0.25	0.25	0.5	
IIs	Garretson gl, 0-2% (I)	950	1	5	0.25	0.25	0.25	0.25	0.25	
IIw	Camarillo l (I)	NA	0	5	0.25	0.25	0.25	0.25	0.25	
IIc	NA									
IIIe	Placentia fsl, 5-9% (I)	750	7	2	0.75	0.75	0.5	0.5	0.75	
IIIs	Tujunga s, 0-9% (I)	950	2	5	0.5		0.5	0.5	0.5	
IIIw	Willows c (I)	NA	0	3	0.25	0.25			0.25	
IIIc	NA									
IVe	Fallbrook fsl, 9-15% (I)	800	12	2			0.75	0.75		
IVs	Tujunga gs, 0-9% (I)	1200	2	5	0.5	0.5	0.5	0.5	0.5	
IVw	Domino sil, saline-alkaline(I)	NA	0	2	NA	0.5			0.25	
IVc	NA									
Ve	NA									
Vw	NA									
Vs	NA									
Vc	NA									
VIe	Linne sicl, 30-50%	700	35	2			1.75	1.5		1.75
VIw	Tujunga ls, channeled, 0-15%	500	5	5						1.5
VIs	Cajalco rocky vfsl, 9-30%	500	12	2			1.25	1.25		1.5
VIc	NA									
VIIe	Vista cosl, 50-75% (I)	600	50	2			1.75	1.75		
VIIs	Cieneba rocky sl, 30-75% (I)	550	40	1			2.0	2.0		
VIIw	Dello s, poorly drained, 0-2%	600	1	5						0.75
VIIc	NA									
VIIIe	Badlands 1/	250	75	1						
VIIIs	Gaviota v ro fsl, 50-95% 2/	325	60	1						
VIIIw	Riverwash 3/									
VIIIc	NA									

1/ Tons of soil loss is 75 T.

2/ Tons of soil loss is 2 T.

3/ Tons of soil loss is 50 T.

STATE California

LRA 20

Form 1W. Dominant Soil, L, S, and T Factors and Estimated Tons Soil Lost to Erosion for Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil	3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems					
					Dryland Grain	Dryland Pasture & Hay	Range Good	Range Poor		
		(ft)	(%)		Tons per acre per year					
I	NA									
IIe	NA									
IIs	NA									
IIw	NA									
IIc	NA									
IIIe	Bull Trail sl, 5-9%	750	6	4	0.5	0.75	0.75	1.25		
IIIs	Chino fsl	NA	0	5	0.25	0.25	0.25	0.5		
IIIw	Foster fsl, slightly wet	NA	0	5	0.25	0.25	0.25	0.5		
IIIc	Reiff fsl, 0-2%	1200	1	5	0.25	0.25	0.25	0.5		
IVe	Calpine sl, 2-9%	900	6	5	0.5	0.75	0.75	1.5		
IVs	Mottsville lcos, 0-9%	1200	3	5	0.25	0.5	0.5	1.0		
IVw	Foster fsl, wet	NA	0	5	0.25	0.25	0.25	0.5		
IVc	Greenfield 1, 0-2%	1200	1	5	0.25	0.25	0.25	0.5		
Ve	NA									
Vw	NA									
Vs	NA									
Vc	NA									
VIe	Holland fsl, 30-50%	700	30	2			1.0	2.0		
VIw	Bishop 1	NA	0	5			0.25	0.5		
VIs	La Posta lcos, 2-9%	700	7	3			0.5	1.25		
VIc	NA									
VIIe	Bancas stl, 50-75%	500	50	2			2.25	3.75		
VIIs	Cieneba kosl, 50-75%	350	50	1			2.5	4.5		
VIIw	Cortina kls, wet, 0-9%	600	2	5			0.5	1.0		
VIIc	NA									
VIIIe	Badland 1/	250	75	1						
VIIIs	Gaviota rsl, 30-85% 2/	350	70	1						
VIIIw	Riverwash 3/	1200	2	5						
VIIIc	NA									

1/ Tons of soil loss is 75T   2/ Tons of soil loss is 2T   3/ Tons of soil loss is 50T

STATE CALIFORNIA

LRA 21

Form 1W. Dominant Soil, L, S, and T Factors
and Estimated Tons Soil Lost to Erosion for
Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil		3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems: Pasture Irrig.	Range Good	Range Poor	Hay Irr.	Woodland
			(ft)	(%)		Tons per acre per year				
I	NA									
IIe	Bidwell 1, 2-5%	(I)	1200	3	5	0.5			0.25	
IIs	Standish fsl	(I)	1200	1	5	0.5			0.25	
IIw	Stillwater cl	(I)	NA	0	5	0.25			0.25	
IIc	Bidwell 1, 0-2%	(I)	1200	1	5	0.5			0.25	
IIIe	Fredrickson 1, 2-5%	(I)	900	3	5	0.5			0.25	
IIIs	Modoc sl, 0-2%	(I)	800	1	4	0.75			0.5	
IIIw	Gazella 1	(I)	1200	1	5	0.5			0.25	
IIIc	Greenhorn 1	(I)	900	1	5	0.5			0.25	
IVe	Kuck sicl, 9-15%	(I)	750	10	5	1.0			0.5	
IVs	Bieber 1, 0-2%	(I)	1000	1	3	0.25			0.25	
IVw	Beckwourth lcos	(I)	1000	1	4	0.75			0.25	
IVc	Simpson 1, 0-2%	(I)	1200	1	5	0.5			0.25	
Ve	NA									
Vw	Greenhorn sl, wet	(I)	1000	1	4	0.25	0.25	0.5	0.25	
Vs	NA									
Vc	NA									
VIe	Windy 1, 15-30%		600	20	4					0.5
VIw	Pasquetti mucky c		NA	0	3	0.5	0.5	0.75	0.25	
VIs	Bieber stl, 5-9%		800	5	2		0.75	1.5		
VIc	NA									
VIIe	Duzel 1, 30-50%		500	35	3		2.0	3.5		
VIIs	Madeline kl, 15-30%		550	25	3		1.5	2.5		
VIIw	Alluvial land		600	2	5		1.0	2.25		
VIIc	NA									
VIIIe	NA									
VIIIs	Rockland 1/		200	65	1					
VIIIw	Riverwash 2/	1200	1200		5					
VIIIc	NA									

1/ Tons of soil loss is 2T.
2/ Tons of soil loss is 50T.

STATE CALIFORNIA

LRA 22

Form 1W. Dominant Soil, L, S, and T Factors and Estimated Tons Soil Lost to Erosion for Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil		3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems: Orchard	Irrigated Pasture & Hay	Woodland			
			(ft)	(%)		Tons per acre per year					
I	NA										
IIe	Aiken l, 2-9%	(I)	900	5	3	.5	.75				
IIs	Tournquist grl, 0-2%	(I)	1000	1	3	.25	.5				
IIw	Oak Glen sl, wet	(I)	1200	1	5	.25	.25				
IIc	NA										
IIIe	Cohasset l, 9-15%	(I)	900	10	2	.5	1.0				
IIIs	Montague c	(I)	1200	1	5	.25	.25				
IIIw	James Canyon sl	(I)	1200	1	5		.25				
IIIc	Massack l	(I)	1000	1	5	.25	.25				
IVe	Aiken l, 15-30%	(I)	750	20	3			.5			
IVs	Bieber sl, 0-2%	(I)	1200	1	2		.5				
IVw	Ophir grl, 0-2%	(I)	1200	1	4		.5				
IVc	NA										
Ve	NA										
Vw	Welch l	(I)	1000	1	5		.25				
Vs	NA										
Vc	NA										
VIe	Shaver cosl, 30-50%		550	45	2			1.0			
VIw	Foster l, wet-climatic variant		1000	1	5		.5				
VIs	Windy stsl, 15-30%		700	20	2			1.25			
VIc	NA										
VIIe	Auberry rol, 50-75%		500	50	2			2.5			
VIIs	Josephine rol, 50-75%		400	60	2			3.0			
VIIw	Alluvial land, sandy		1000	5	5		.75				
VIIc	Bishop l, drained		1200	1	5		.25				
VIIIe	Badlands 1/		1250	75	1						
VIIIs	Iron Mountain vstl, 30-75% 2/		500	60	1						
VIIIw	Riverwash 3/		1200	1	5						
VIIIc	NA										

1/ Tons of soil loss is 75T
2/ Tons of soil loss is 2T
3/ Tons of soil loss is 50T

STATE OREGON

LRA 23

Form 1W. Dominant Soil, L, S, and T Factors and Estimated Tons Soil Lost to Erosion for Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil	3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems: Row Crop, Grain Hay	Hay, Pasture	Range Good	Range Poor		
		(ft)	(%)	Tons per acre per year						
I	Jett sil (I)	800	1	5	2	1				
IIc	Bidwell l, 2-4% (I)	1000	3	2	3	1				
IIs	Virtue sil, 0-2% (I)	600	2	2	2	1				
IIw	Wingville sil (I)	800	1	5	2	1				
IIc	Harriman l, 0-2% (I)	500	1	4	2	1				
IIIe	Fordney ls, 0-2% (I)	300	1	4	2 1/	1 1/				
IIIs	Umapine sil, 0-3% (I)	600	1	5	5	2				
IIIw	Baldock sil, 0-2% (I)	1200	1	5	5	2				
IIIc	None									
IVe	Bonnick ls, 0-2% (I)	400	1	2	2 1/	1 1/				
IVs	Hager l, alkali var, 1-15% (I)	600	3	2		1				
IVw	Hovey sicl (I)	NA	0	3	0	0				
IVc	Fort Rock l (I)	1200	1	2	2	1				
Ve	None									
Vw	Crump muck	NA	0	5			0	0		
Vs	None									
Vc	None									
VIe	Lookout stl, 2-45%	800	25	2			.5	1.5		
VIw	Boulder Lake c	NA	0	3			0	0		
VIs	Horning lfs, 5-25%	400	12	5			.3 1/	1 1/		
VIc	Nevador fsl, 0-2%	1200	1	2			0	.3		
VIIe	Lyonman sl, 30-50%	800	40	2			.5	1.5		
VIIs	Hart vksil, 0-15%	800	6	1			.3	1		
VIIw	None									
VIIc	None									
VIIIe	Badlands 2/	1200	50							
VIIIs	Rock Outcrop	400	200							
VIIIw	Playa		0							
VIIIc										

1/ This does not show soil loss due to wind erosion which may be severe.
2/ Tons of soil loss is 50T.

STATE IDAHO

LRA 25

Form 1W. Dominant Soil, L, S, and T Factos and Estimated Tons Soil Lost to Erosion for Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil	3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems: Grain-fallow	Rangeland, Good cover	Rangeland, Poor cover	Irrigated Hay & Grain	
		(ft)	(%)		Tons per acre per year				
I	NA								
IIe	NA								
IIs	NA								
IIw	Fluvaquent. Haploxeroll sal. (I)	400	1	4		0	0		
IIc	Paniogue 1, deep, 0-2% (I)	900	1	4				0	
IIIe	Aridic Calcic Argixerolls	300	9	4	6	0	4		
IIIs	Pocker sil, 0-2% (I)	600	1	2				1	
IIIw	Welch 1 (I)	800	1	3				0	
IIIc	Fluventic Haploxerolls (I)	400	1	4		0	0	0	
IVe	Justesen 1, 4-12%	300	7	4	5	1	3		
IVs	Eames grl, 2-8%	300	4	3	3	0	1		
IVw	Camascreek 1, 0-2%	300	1	5		0	0		
IVc	NA								
Ve	NA								
Vw	Aquic Cryoborolls	100	1	5		0	0		
Vs	NA								
Vc	NA								
VIe	Toeja gl, 15-30%	400	20	3		2	15		
VIw	Camascreek 1, wet, 0-2%	100	3	5		0	0		
VIs	Typic Argixerolls, rocky	100	12	2		1	3		
VIc	Xerollic Camborthid	300	1	3		1	2		
VIIe	Argic Pachic Cryoborolls, st	100	45	2		2	20		
VIIs	Lithic Xerollic Haplargids vst	200	8	1		1	2		
VIIw	Humboldt sicl, str. saline	NA	0	3		0	0		
VIIc	Rad sil, 2-8%	500	4	3		0	3		
VIIIe	None								
VIIIs	Rockland 1/	50	15	1					
VIIIw	Playas 2/	NA	0	5					
VIIIc	None								

1/Tons of soil losr is 5T. 2/ Tons of soil loss is 0T.

STATE UTAH

LRA 28

Form 1W. Dominant Soil, L, S, and T Factors and Estimated Tons Soil Lost to Erosion for Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil	3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems: WHEAT FALLOW (Dry Crop)	ROTATED CROPLAND IRRIGATED	PASTURE	GOOD RANGE	POOR RANGE
		(ft)	(%)		Tons per acre per year				
I	Parleys 1, 0-3%	(I): 1200	2	4		1.7			
IIc	Genola 1, 1-2%	(I): 1200	2	5		2.3			
IIs	Escalante fsl, 1-2%	(I): 1200	2	3		1.7			
IIw	Greenson 1, 0-3%	(I): 1200	3	2		1.7			
IIc	Genola 1, 0-1%	(I): 1200	1	5		1.5			
IIIe	Kearns sil, 3-6%	1000	6	3	10.3				
IIIs	Taylorsville sicl, 1-3%	(I): 1000	2	2		1.3			
IIIw	Logan sicl	(I): 1200	2	2		9			
IIIc	Timpanogos sl, 1-3%	1200	2	4	4.1			1	1.5
IVe	Thiokol sil, 1-6%	1000	6	3	11.9			1.2	1.8
IVs	Bingham 1, 1-6%	600	6	1	5.2			1.2	1.8
IVw	Airport sil	(I): 1000	2	2			0.3		
IVc	Hansel sil, 0-1%	1200	1	3	3.6			1.2	1.8
Ve	NA								
Vw	Roshe Springs sil	(I): 600	2	2			0.1		
Vs	NA								
Vc	NA								
VIe	Middle sil, 10-30%	400	20	2				1.5	2.0
VIw	Chipman sicl	(I): 1000	2	2					
VIs	Abela gl, 10-20%	400	10	2				1.0	1.5
VIc	NA								
VIIe	Penoyer sil, 1-3%	1000	3	5				3.0	4.6
VIIs	Decca 1, 1-3%	1000	3	1				3.0	4.5
VIIw	Leland fsl	1000	1	2				1.0	1.0
VIIc	Penoyer sil, 0-1%	1200	1	5				3.0	4.6
VIIIe	NA								
VIIIs	Duneland 1/ (Poor Range)	50	20	5					
VIIIw	Saltair sicl (Poor Range) 2/	1000		1					
VIIIc	NA								

1/ Tons soil loss 5T

2/ Tons soil loss 1.0

STATE CALIFORNIA

LRA 30

Form 1W. Dominant Soil, L, S, and T Factors
and Estimated Tons Soil Lost to Erosion for
Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil	3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems					
					Alfalfa	Irrig. Row Crop	Irrig. Small Grain		Range	
		(ft)	(%)		Tons per acre per year					
I	Rosamond sicl (I)	NA	0	5	0.25	0.25	0.25			
IIe	Hesperia fsl, 2-5% (I)	1200	2	5	0.25	0.25	0.25			
IIs	Mohave sl (I)	1200	1	3	0.25	0.25	0.25			
IIw	Calico fsl (I)	NA	0	5	0.25	0.25	0.25			
IIc	NA									
IIIe	Sunrise sl, 2-5% (I)	800	5	1	0.5		0.5			
IIIs	Rosamond sicl, alkali (I)	NA	0	5	0.25		0.25			
IIIw	NA									
IIIc	NA									
IVe	Cajon fs, 2-9% (I)	1000	2	5	0.75	0.75	0.75			
IVs	Brazito s (I)	1200	1	5	0.5	0.5	0.5			
IVw	Imperial sic (I)	NA	0	2	0.25	0.25	0.25			
IVc	NA									
Ve	NA									
Vw	NA									
Vs	NA									
Vc	NA									
VIe	NA									
VIw	NA									
VIs	NA									
VIc	NA									
VIIe 2/	Calvista sl, 9-15%	500	10	1					2.5	
VIIs	Bittersprings grl, 2-9%	1000	7	5					2.5	
VIIw	Soboga ls, wet	1000	2	5					3.0	
VIIc	Rosamond sicl	NA	0	5					1.0	
VIIIe	Badlands 1/	250	75							
VIIIs	Daggett stls, 0-9% 2/	1200	1							
VIIIw	Playa 3/	NA	0							
VIIIc	NA									

1/ Tons of soil loss is 75 T. 2/ Tons of soil loss is 0.5 T. 3/ Tons of soil loss is 0 T.

STATE CALIFORNIA

LRA 31

Form 1W. Dominant Soil, L, S, and T Factors and Estimated Tons Soil Lost to Erosion for Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil	3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems					
					Row Crops	Alfalfa	Irr. Field Crops	Orchard		
		(ft)	(%)		Tons per acre per year					
I	Indio sil (I)	NA	0	5	.25	.25	.25	.25		
IIe	NA									
IIs	Gilman fsl (I)	1200	1	5	.25	.25	.25	.25		
IIw	Glenbar sicl, wet (I)	1200	1	5	.25	.25	.25	.25		
IIc	NA									
IIIe	NA									
IIIs	Rositas fs (I)	1200	1	5	.5	.5	.5	.5		
IIIw	Meloland fsl (I)	NA	0	5	.25	.25	.25	.25		
IIIc	NA									
IVe	NA									
IVs	Carrizo grs (I)	1200	1	5	.5	.5	.5	.5		
IVw	Imperial sic (I)	NA	0	5	.25	.25	.25			
IVc	NA									
Ve	NA									
Vw	NA									
Vs	NA									
Vc	NA									
VIe	NA									
VIw	NA									
VIs	NA									
VIc	NA									
VIIe	NA									
VIIs	NA									
VIIw	NA									
VIIc	NA									
VIIIe	Badland 2/	250	75	1						
VIIIs	Rock Land 3/	300	70	1						
VIIIw	Riverwash 4/	1200	2	5						
VIIIc	Indio sil 5/	NA	0	5						

1/ Unless Irrigated, all soils are class VIII

2/ Tons of soil loss is 75T

3/ Tons of soil loss is 2T

4/ Tons of soil loss is 50T

5/ Tons of soil loss is 1T

STATE WYOMING

LRA 34

Form 1W. Dominant Soil, L, S, and T Factors and Estimated Tons Soil Lost to Erosion for Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil		3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems: Small Grain and Hay or Pasture	Hay or Pasture with occasional Establish.	Permanent Hay or Pasture	Range Good	Range Poor
			(ft)	(%)		Tons per acre per year				
I	Ravola 1, Ext. season	(I)	1200	1	5	.5	.4	.3		
IIe	NA									
IIs	Moffat, 0-3%	(I)	1200	2	3	2.0	2.0	1.0		
IIw	NA									
IIc	Ravola 1	(I)	1200	1	5	.5	.4	.3		
IIIe	Alcova sl, 0-3%	(I)	1200	2	5	3	2.5	2		
IIIs	Crowheart 1, 0-3%	(I)	1200	2	3	3	2.5	2		
IIIw	Canninger 1, 0-3%	(I)	100	2	5	3	2.5	2		
IIIc	Ryan Park lfs, 0-3%	(I)	1200	2	5	2	1.5	.1	1	
IVe	High Park fsl, 3-6%		1200	4	5				1	5
IVs	Fluvents, saline	(I)	400	1	-	2	1.5	1		
IVw	Canninger 1, 0-3%		100	2	5				1	3
IVc	Havre 1, 0-3%		1000	2	5				1	3
Vo	NA									
Vw	Typic Fluvaquents		400	1	-				0	1
Vs	NA									
Vc	NA									
VIe	Ryan Park lfs, 3-6%		1200	4	5				2	10
VIw	Aquic Ustifluvents		1200	2	5				1	3
VIs	Space City lfs, 6-10%		50	8	5				3	12
VIc	Ryan Park lfs, 0-3%		1200	2	5				1	3
VIIe	Blazon 1, 3-10%		200	8	2				2	10
VIIs	Shinbara 1, 6-30%		200	20	1				1	5
VIIw	Typic Torrifluvents, flooded		300	2	1				1	3
VIIc	Typic Torrifluvents		1200	1	5				1	3
VIIIe	Gullied land 1/		40	30	-					
VIIIs	Rock outcrop		200	60	-					
VIIIw	Marsh land		NA	0	-					
VIIIc	NA		-	-	-					

1/ Tons of soil loss is-25 T.

STATE WYOMING

LRA 34

Form 1W. Dominant Soil, L, S, and T Factors and Estimated Tons Soil Lost to Erosion for Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil		3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems: Small Grain and Hay or Pasture	Hay or Pasture with occasional Establish.	Permanent Hay or Pasture	Range-Good	Range Poor
			(ft)	(%)		Tons per acre per year				
I	Ravola l, Ext. season	(I)	1200	1	5	.5	.4	.3		
IIe	NA									
IIs	Moffat, 0-3%	(I)	1200	2	3	2.0	2.0	1.0		
IIw	NA									
IIc	Ravola l	(I)	1200	1	5	.5	.4	.3		
IIIe	Alcova sl, 0-3%	(I)	1200	2	5	3	2.5	2		
IIIs	Crowheart l, 0-3%	(I)	1200	2	3	3	2.5	2		
IIIw	Canninger l, 0-3%	(I)	100	2	5	3	2.5	2		
IIIc	Ryan Park lfs, 0-3%	(I)	1200	2	5	2	1.5	1	1	
IVe	High Park fsl, 3-6%		1200	4	5				1	5
IVs	Fluvents, saline	(I)	400	1	-	2	1.5	1		
IVw	Canninger l, 0-3%		100	2	5				1	3
IVc	Havre l, 0-3%		1000	2	5				1	3
Ve	NA									
Vw	Typic Fluvaquents		400	1	-				0	1
Vs	NA									
Vc	NA									
VIe	Ryan Park lfs, 3-6%		1200	4	5				2	10
VIw	Aquic Ustifluvents		1200	2	5				1	3
VIs	Space City lfs, 6-10%		50	8	5				3	12
VIc	Ryan Park lfs, 0-3%		1200	2	5				1	3
VIIe	Blazon l, 3-10%		200	8	2				2	10
VIIs	Shinbara l, 6-30%		200	20	1				1	5
VIIw	Typic Torrifluvents, flooded		300	2	1				1	3
VIIc	Typic Torrifluvents		1200	1	5				1	3
VIIIe	Gullied land 1/		40	30	-					
VIIIs	Rock outcrop		200	60	-					
VIIIw	Marsh land		NA	0	-					
VIIIc	NA		-	-	-					

1/ Tons of soil loss is 25 T.

STATE ARIZONA

LRA 35

Form 1W. Dominant Soil, L, S, and T Factors and Estimated Tons Soil Lost to Erosion for Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1.Capability Class and Subclass	2.Dominant Soil	3.Dom Slope Length	4.Dom % Slope	5.T Factor	6. Estimate Soil Losses for Selected Cropping Systems					
					Irrig Row Crop	Irrig Close Grown Crop	Range POOR	Range GOOD	Forest	Dryland grain and hay
		(ft)	(%)		Tons per acre per year					
I	Clovis sandy loam, 0-1% (I)	NA	0	3	0.25	0.12				
IIe	Tours cl, 1-3% (I)	800	2	4	0.4	0.2				
IIs	Jocity scl, sal-alk, 0-1% (I)	NA	0	3	0.2	0.3				
IIw	Jocity scl, 0-1%, flooded (I)	NA	0	3	0.5	0.3				
IIc	Ravada cl, 0-1% (I)	1200	1	5	0.2	0.1				
IIIe	Jocity scl, 3-5% (I)	600	4	2	0.8	0.4				
IIIs	Navajo c, 0-1% (I)	NA	0	4	0.4	0.2				
IIIw	Navajo c, 0-1%, flooded (I)	NA	0	4	0.1	0.3				
IIIc	Aridic Argiboroll, flm (I)	1200	2	3	NA	NA				
IVe	Clovis sl, 5-10% (I)	600	7	2	1.2	0.5				
IVs	Navajo c, 0-1%, sal-alk (I)	NA	0	4	0.6	0.3				
IVw	Ferron 1 (I)	300	2	2	NA	0.2				
IVc	Aridic Argiustoll, flmme	300	2	3	NA	NA	2.0	0.2		0.2
Ve	NA									
Vw	NA									
Vs	NA									
Vc	NA									
VIe	Moencopi ls, 8-15%	600	10	0.5			3.0	0.35		
VIw	Jocity scl, 0-1%, flooded	NA	0	3			2.5	0.40		
VIs	Moencopi ls, 0-8%	400	6	0.5			3.5	0.25		
VIc	Clovis sl, 0-1%	NA	0	3			4.5	0.30		
VIIe	Moencopi vfls	1200	40	0.5			2.0	0.15		
VIIs	Moencopi v rocky ls	1200	20	0.5			2.0	0.15		
VIIw	NA									
VIIc	Typic Torrifluvent, flmme	1200	1	5.0			2.0	0.15		
VIIIe	Gullied land 1/	1200	1	1			NA	NA		
VIIIs	Rock Outcrop	1200	50	NA			NA	NA		
VIIIw	NA									
VIIIc	NA									

1/ Tons of soil loss is 50T

STATE NEW MEXICO

LRA 36 (New Mexico & Arizona Plateaus & Mesas)

Form 1W. Dominant Soil, L, S, and T Factors
and Estimated Tons Soil Lost to Erosion for
Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil	3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems: Rangeland Good Cover	Rangeland Poor Cover	Woodland	Corn Silage Barley	Cont. Small Grain	Hay Alfalfa Small Grain
		(ft)	(%)	Tons per acre per year						
I	Penistaja fsl, 0-1% (I)	1200	1	5				.44		.11
IIe	Fruitland sl (I)	1200	1	5				.44		.11
IIs	San Mateo l, sli saline (I)	1200	1	5				.73		.18
IIw	NA									
IIc	NA									
IIIe	El Rancho scl, 3-9%, (I)	1000	4	5				2.54		.63
IIIs	San Mateo l, mod saline (I)	1200	1	5				.73		.18
IIIw	NA									
IIIc	NA									
IVe	NA									
IVs	Pureco c (I)	1200	1	5				1.12		.28
IVw	Prewitt l	1200	0	5	.06	.11			.04	
IVc	NA									
Ve	NA									
Vw	NA									
Vs	NA									
Vc	NA									
VIe	Clovis l, 5-9%	1200	6	5	3.64	7.28				
VIw	Werlow l	250	1	5	.28	.42				
VIs	Rudd stl, 3-9%	750	6	1	4.59	6.12				
VIc	Clovis l, 0-5%	1200	1	5	.7	1.12				
VIIe	Prieta grl, 9-25%	500	20	1	24.48	32.64				
VIIs	Persayo sicl, 9-25%	1000	15	2	30.96	86.69				
VIIw	NA									
VIIc	NA									
VIIIe	Badlands 1/	750	45	5						
VIIIs	Riverwash 2/	1200	1	5						
VIIIw	NA									
VIIIc	NA									

1/ Tons of soil loss 100T

2/ Tons of soil loss 75T

STATE NEW MEXICO

LRA 37 (San Juan River Valley, Mesas, and Plateaus)

Form 1W. Dominant Soil, L, S, and T Factors and Estimated Tons Soil Lost to Erosion for Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil	3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems					
					RANGELAND					
					Cover GOOD	Cover POOR	Corn Sil Barley			
		(ft)	(%)		Tons per acre per year					
I	Doak l, 0-1% (I)	1000	1	5	0.98	1.26	0.73			
IIe	Fruitland sl (I)	1200	2	5	1.22	1.57	0.91			
IIs	Billings sicl, 0-1% (I)	1200	1	5	1.51	1.94	1.12			
IIw	NA									
IIc	NA									
IIIe	Turley l, 3-5% (I)	1200	4	5	3.97	5.10	2.95			
IIIs	Fruitland l, saline (I)	1200	1	5	0.84	1.12	0.73			
IIIw	NA									
IIIc	NA									
IVe	Sheppard ls, 2-5% (I)	500	3	5	1.19	2.08	1.55			
IVs	Sheppard ls, 0-2% (I)	1200	1	5	0.34	0.60	0.44			
IVw	Werlow l (I)	NA	0	5	0.17	0.30	0.60			
IVc	NA									
Ve	NA									
Vw	NA									
Vs	NA									
Vc	NA									
VIe	Negeesi sl, 0-2%	1200	2	3	1.22	1.57	--			
VIw	Werlow l	NA	0	5	0.25	0.38	--			
VIs	Navajo cl, saline	1200	1	5	1.72	1.94	--			
VIc	San Mateo l, 0-3%	1200	1	5	2.85	3.52	--			
VIIe	Farb stl, 5-25%	1000	20	1	82.56	92.88	--			
VIIs	Deaver c, 0-3%	1200	2	5	3.53	3.97	--			
VIIw	NA									
VIIc	Doak l, 1-3%	1200	2	5	2.01	2.58	--			
VIIIe	Badlands 1/	750	30	5	NA	NA	--			
VIIIs	Rock land 2/	750	30	1	NA	NA	--			
VIIIw	NA									
VIIIc	NA									

1/ Tons of soil loss is 100T

2/ Tons of soil loss is 2T

STATE ARIZONA

LRA 39

Form 1W. Dominant Soil, L, S, and T Factors
and Estimated Tons Soil Lost to Erosion for
Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil	3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems				
					Irrig Row Crop	Irrig Close Grown Crop	Range POOR	Range GOOD	Forest
		(ft)	(%)		Tons per acre per year				
I	Wineg sl, 0-1% (I)	NA	0	1	0.4	0.1			
IIe	Wineg sl, 1-3% (I)	800	2	1	0.8	0.2			
IIs	Lynx l, 0-1%, sal-alk (I)	NA	0	3	0.7	0.2			
IIw	NA								
IIc	Sponseller gl, 0-2% (I)	500	1	1	0.6	0.2			
IIIe	Poley grl, 103% (I)	800	2	2	0.3	0.1			
IIIs	Springerville c, 0-1% (I)	NA	0	3	0.6	0.1			
IIIv	Lynx l, wet var, 0-1% (I)	NA	0	3	0.7	0.2			
IIIc	Clover Springs scl, 0-1% (I)	NA	0	3	0.6	0.1			
IVe	Sponseller gl, 5-10%	300	8	1	1.2	0.6			
IVs	Thunderbird grcl, 0-5% (I)	600	2	2	0.8	0.2			
IVw	NA								
IVc	NA								
Ve	NA								
Vw	NA								
Vs	NA								
Vc	NA								
VIe	Showlow grcl, 8-15%	1200	10	2			2.5	0.20	NA
VIw	NA								
VIs	Thunderbird cl, 0-8%	1000	4	1			3.5	0.25	NA
VIc	Gordo sl, 2-25%	1200	15	3			NA	NA	0.35
VIIe	Bandera grl, 2-30%	1200	20	0.5			4.0	0.25	NA
VIIs	Gaddes grsl, 3-35%	1200	20	0.5			2.5	0.20	NA
VIIw	NA								
VIIc	NA								
VIIIe	NA								
VIIIs	Rock Outcrop	1200	30	NA			NA	NA	NA
VIIIw	NA								
VIIIc	NA								

STATE ARIZONA

LRA 40

Form 1W. Dominant Soil, L, S, and T Factors
and Estimated Tons Soil Lost to Erosion for
Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil	3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems				
					Irrig Row Crop	Irrig Close Grown Crop	Range POOR	Range GOOD	Forest
		(ft)	(%)		Tons per acre per year				
I	Gilman l, 0-1% (I)	NA	0	5	0.6	0.3			
IIe	Antho sl, 1-3% (I)	800	2	5	0.8	0.4			
IIs	Glenbar cl, 0-1%, sal-alk (I)	NA	0	5	0.7	0.35			
IIw	Estrella l, 0-2%, flooded	800	1	3	0.6	0.3			
IIc	NA								
IIIe	Vint ls, 3-5% (I)	600	4	5	2.2	0.8			
IIIs	Gadsden c, 0-1% (I)	NA	0	5	0.4	0.06			
IIIw	NA								
IIIc	NA								
IVe	NA								
IVs	Cashion c, sal-alk, 0-1% (I)	NA	0	2	0.7	0.35			
IVw	NA								
IVc	NA								
Ve	NA								
Vw	NA								
Vs	NA								
Vc	NA								
VIe	NA								
VIw	NA								
VIs	NA								
VIc	NA								
VIIe	Cachado vgrl, 5-10%	1200	8	0.5			4.0	0.35	
VIIs	Growler grl, 0-5%	1200	4	2			3.0	0.25	
VIIw	Brior [illegible], flooded, 0-2%	500	1	4			2.0	0.15	
VIIc	Moha[illegible], 0-1%	1200	1	3			2.5	0.20	
VIIIe	NA								
VIIIs	Rock Outcrop	1200	30	NA			NA	NA	
VIIIw	NA								
VIIIc	NA								

STATE ARIZONA

LRA 41

Form 1W. Dominant Soil, L, S, and T Factors and Estimated Tons Soil Lost to Erosion for Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil		3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems Irrig. Row Crop	Irrig. Close Grown Crop	Range POOR	Range GOOD		
			(ft)	(%)		Tons per acre per year					
I	Elfrida sicl, 0-2%	(I)	NA	0	3	0.3	0.12				
IIe	Comoro sl, 2-5%	(I)	800	3	4	1.2	0.4				
IIs	Anthony sl, 0-2%	(I)	600	1	5	0.6	0.3				
IIw	NA										
IIc	NA										
IIIe	Tubac scl, 0-5%	(I)	1200	2	1	0.5	0.2				
IIIs	Continental scl, 0-2%	(I)	8	1	2	0.4	0.1				
IIIw	NA										
IIIc	NA										
IVe	NA										
IVs	NA										
IVw	NA										
IVc	NA										
Ve	NA										
Vw	NA										
Vs	NA										
Vc	NA										
VIe	Caralampi sl, 10-60%		1000	40	0.5			4.5	0.25		
VIw	Cogswell cl, 0-2%		1200	1	3			2.5	0.20		
VIs	NA										
VIc	Elfrida sicl, 0-2%		1200	NA	3			3.5	0.15		
VIIe	Cellar vgrsl, 3-60%		1200	30	0.5			3.0	0.20		
VIIs	House Mountain stl, 2-50%		1200	30	0.5			4.0	0.15		
VIIw	NA										
VIIc	NA										
VIIIe	NA										
VIIIs	Rock outcrop		1200	30	NA			NA	NA		
VIIIw	NA										
VIIIc	NA										

STATE NEW MEXICO

LRA 42 (South Desertic Basins, Plains, and Mountains)

Form 1W. Dominant Soil, L, S, and T Factors and Estimated Tons Soil Lost to Erosion for Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil	3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems				
					RANGELAND		Woodland (NA)	Cotton Barley	Cotton Barley Alfalfa (3yr)
					Cover GOOD	Cover POOR			
		(ft)	(%)		Tons per acre per year				
I		1200	1						
IIe	Gila fsl, 0-1% (I)	1200	1	5	--	--	--	0.43	0.97
IIs	Agua l, 0-1% (I)	NA	0	3	--	--	--	0.70	1.60
IIw	NA								
IIc	NA								
IIIe	Vinton fsl, 1-3% (I)	1200	2	5	--	--	--	0.87	1.99
IIIs	NA								
IIIw	NA								
IIIc	NA								
IVe	NA								
IVs	Arizo grsl, 0-1% (I)	1200	1	5	--	--	--	0.43	0.97
IVw	NA								
IVc	NA								
Ve	NA								
Vw	NA								
Vs	NA								
Vc	NA								
VIe	Grabe fsl, 0-3%	1200	1	5	0.34	0.60	--	--	--
VIw	NA								
VIs	NA								
VIc	Pima sil, 0-1%	1200	1	5	0.86	1.51	--	--	--
VIIe	NA								
VIIs	NA								
VIIw	Fife grl, flooded, 0-5%	750	4	5	5.64	7.25	--	--	--
VIIc	NA								
VIIIe	Badlands 1/	750	30	5	--	--	--	--	--
VIIIs	Rock land 2/	750	20	1	--	--	--	--	--
VIIIw	NA								
VIIIc	NA								

1/ Tons of soil loss is 100T

2/ Tons of soil loss is 2T

STATE Idaho

LRA 43

Form 1W. Dominant Soil, L, S, and T Factors and Estimated Tons Soil Lost to Erosion for Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil	3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems				
					Wheat Peas	Grain Hay	Range Good Cover	Range Poor Cover	Woodland
		(ft)	(%)		Tons per acre per year				
I	NA								
IIe	Nez Perce sil, 4-8%	300	6	3	3	2	0	2	
IIs	Depew sic, 0-2%	500	1	5		1	0	1	
IIw	Latah sil, 0-4%	200	2	4	2	1	0	0	
IIc	Carlinton sil, 0-4%	600	2	4	2	1	0	1	
IIIe	Kooskia sil, 4-8%	400	6	4	7	5			1
IIIs	Mires l, 2-7%	700	4	3		2	0	2	
IIIw	NA								
IIIc	Santa sil, 0-4%	500	2	4		3			1
IVe	Santa sil, 0-30%	200	12	4		11			3
IVs	Bonner - grsil, 4-8%	300	6	2					1
IVw	Roseberry l, 0-2%	200	1	5		0	0	0	
IVc	Alex l, 0-2%	200	1	1		0	0	1	
Ve	NA								
Vw	Lam l	100	1	1		0	0	0	
Vs	NA								
Vc	NA								
VIe	Jughandle l, 0-30%	100	15	2					2
VIw	Slocum l, cold, 0-4%	500	2	2			0	0	
VIs	Klicker rol, 0-30%	100	15	2					1
VIc	NA								
VIIe	Jughandle l, 30-60%	100	45	2					2
VIIs	Shoeffler stsil, 30-60%	100	45	2					2
VIIw	NA								
VIIc	NA								
VIIIe	Gwin sil, 50-80% 1/	50	60	1					
VIIIs	Rockland 2/	100	45	1					
VIIIw	Alluvial Land 3/	100	1	1					
VIIIc	None								

1/ Tons of soil loss is 10T   2/ Tons of soil loss is 5T   3/ Tons of soil loss is 2T

STATE COLORADO

LRA 45

Form 1W. Dominant Soil, L, S, and T Factors
and Estimated Tons Soil Lost to Erosion for
Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil	3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems					
					Sm.grain Hay	Irrig. Hay	Range-land POOR	Range-land GOOD		
		(ft)	(%)		Tons per acre per year					
I	NA									
IIe	NA									
IIs	NA									
IIw	NA									
IIc	NA									
IIIe	NA									
IIIs	NA									
IIIw	NA									
IIIc	NA									
IVe	Shrine cl, 3-9% (I)	500	5	5	4	2	NA	NA		
IVs	NA	--	--	--	--	--	--	--		
IVw	NA	--	--	--	--	--	--	--		
IVc	NA	--	--	--	--	--	--	--		
Ve	NA	--	--	--	--	--	--	--		
Vw	Rosane loam, 1-5% (I)	1000	3	3	NA	1	NA	NA		
Vs	NA	--	--	--	--	---	--	--		
Vc	Bosler sl, 1-8% (I)	800	4	5	NA	1	NA	NA		
VIe	Tomichi sl, 5-25%	1200	15	2	NA	NA	4.0	0.5		
VIw	Almont sil, 5-10% (I)	500	7	5	NA	NA	0.5	0.1		
VIs	NA	--	--	--	--	--	--	--		
VIc	NA	--	--	--	--	—	--	--		
VIIe	Bross, grsl, 9-45%	1000	25	5	NA	NA	1.0	0.25		
VIIs	Meredith, vstl, 8-50%	800	30	2	NA	NA	0.5	0.1		
VIIw	Vasquez stsl, 5-20%	300	10	5	NA	NA	0.5	0.1		
VIIc	NA	--	--	--	--	--	--	--		
VIIIe	Shale outcrop 1/	50	40	NA	NA	NA	NA	NA		
VIIIs	Rock outcrop	50	50	NA	NA	NA	NA	NA		
VIIIw	NA	--	--	--	--	--	--	--		
VIIIc	NA	--	--	--	--	--	--	--		

1/ Tons soil loss-6T

STATE UTAH

LRA 47

Form 1W. Dominant Soil, L, S, and T Factors and Estimated Tons Soil Lost to Erosion for Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil		3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems				
						WHEAT FALLOW (Dry Crop)	ROTATED CROP (Irr.)	PASTURE	GOOD RANGE	POOR RANGE
			(ft)	(%)		Tons per acre per year				
I	Ustic Torrifluvents flm	(I)	1200	1	5		1.5			
IIe	Genola l, 1-2%	(I)	1200	2	5		2.1			
IIs	Ustic Torrifluvents colm	(I)	600	1	3		1.7			
IIw	Green River l, 0-1%	(I)	300	1	4		1.7			
IIc	Redfield sil, 0-1%	(I)	1200	1	5		1.6			
IIIe	Quaker sicl, 1-2%	(I)	1200	2	5		1.7			
IIIs	Annabella sl, 1-2%	(I)	500	2	2		2.5			
IIIw	Ephraim sicl	(I)	1000	2	2			.2		
IIIc	Rasband l, 1-3%	(I)	1200	2	3		1.6			
IVe	Birdow vfsl, 4-8%		600	4	5	8.0			1.5	2.0
IVs	Sanpete gfsl, 2-5%	(I)	600	5	1		2.9			
IVw	Kovich l	(I)	500	2	1			.1		
IVc	Aridic Calcixerolls flm		600	2	2	9.3			1.2	1.7
Ve										
Vw	Fluvaquents		600	2	1				.5	1.0
Vs										
Vc										
VIe	Henefer sil, 10-25%		500	25	3				2.0	3.0
VIw	Fluvaquents		600	2	1				.5	1.0
VIs	Lizzant stl, 4-20%		500	15	2				1.0	2.0
VIc	Mitch sil, 0-2%		200	2	5				2.5	3.0
VIIe	Flygare l, 40-60%		500	50	3				1.0	1.0
VIIs	Daybell l, 40-65%		500	50	2				1.0	1.0
VIIw	Poganeab cl, 1-3%		600	2	1				3.0	3.0
VIIc	Redfield sil, 0-1%		1200	1	5				.6	1.5
VIIIe	Gullied land 1/		40	2	5					
VIIIs	Rock outcrop									
VIIIw	Riverwash 2/		100	1	1					
VIIIc										

1/ Tons soil loss 100

2/ Tons soil loss 75T

STATE COLORADO

LRA 48 (Includes Res. Area 49)

Form 1W. Dominant Soil, L, S, and T Factors
and Estimated Tons Soil Lost to Erosion for
Selected Cropping Systems

USDA - SCS
Attachment to EVT-2

1. Capability Class and Subclass	2. Dominant Soil		3. Dom Slope Length	4. Dom % Slope	5. T Factor	6. Estimate Soil Losses for Selected Cropping Systems					
						Pasture and Hayland	Dry Beans	Dry Wheat	Sugar Beets and Corn	Range POOR Cond.	Range GOOD Cond.
			(ft)	(%)		Tons per acre per year					
I	Fruita loam, 0-1%	(I)	800	1	5	2	--	--	4	NA	NA
IIe	Fruita loam, 1-3%	(I)	600	2	5	2	--	--	5	NA	NA
IIs	Billings scl, 0-1%	(I)	1200	1	5	2	--	--	4	NA	NA
IIw	NA		--	--	--	--	--	--	--	NA	NA
IIc	NA		--	--	--	--	--	--	--	NA	NA
IIIe	Holdermann sl, 3-5%		500	4	5	NA	10	20	5	5.0	0.25
IIIs	Colonne cl, 0-2%	(I)	1000	1	5	2	NA	NA	5	NA	NA
IIIw	Uncompahgre sl, 0-3%		1000	1	5	2	NA	NA	NA	NA	NA
IIIc	Collbran l, 0-3%		500	2	5	NA	5	10	NA	2.0	0.25
IVe	Bostwick sl, 5-10%	(I)	300	8	5	5	NA	NA	5	NA	NA
IVs	Christianburg c, 0-2%	(I)	1200	1	5	2	NA	NA	5	NA	NA
IVw	Yampa l, 0-1%	(I)	1200	1	5	.25	NA	NA	NA	NA	NA
IVc	Cerro cl, 0-3%		500	2	5	NA	NA	10	NA	5.0	0.25
Ve	NA		--	--	--	--	--	--	--	--	--
Vw	Big Blue l, 0-5%		1200	1	5	.25	NA	NA	NA	0.5	0.1
Vs	Valmont kcl, 1-5%		1000	3	5	NA	NA	NA	NA	0.5	0.25
Vc	Anvik l, 0-3%		300	2	5	NA	NA	NA	NA	0.5	0.25
VIe	Evanston l, 5-20%		500	10	5	NA	NA	NA	NA	5.0	0.5
VIw	Gas Creek grsl, 0-3%		1000	1	2	NA	NA	NA	NA	0.5	0.1
VIs	Gateview kl, 2-8%		500	4	5	NA	NA	NA	NA	1.0	0.25
VIc	Evanston l, 1-5%		800	3	5	NA	NA	NA	NA	1.0	0.25
VIIe	Perlin grl, 5-45%		1000	20	5	NA	NA	NA	NA	5.0	0.5
VIIs	Carbol vrsl, 15-60%		800	35	1	NA	NA	NA	NA	0.5	0.1
VIIw	Vasquez stsl, 5-20%		300	10	5	NA	NA	NA	NA	0.5	0.1
VIIc	Williams l, 0-5%		1200	3	5	NA	NA	NA	NA	1.0	0.25
VIIIe	Badland 1/		50	30	NA	NA	NA	NA	NA	NA	NA
VIIIs	Rock outcrop		50	50	NA	NA	NA	NA	NA	NA	NA
VIIIw	NA		NA	NA	NA	NA	NA	NA	NA	NA	NA
VIIIc	NA		NA	NA	NA	NA	NA	NA	NA	NA	NA

1/ Tons of soil loss--8T

APPENDIX F

REPRODUCTION OF "PESTICIDE RESIDUE LEVELS IN SOILS, FY1969--NATIONAL SOILS MONITORING PROGRAM*

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* Published in Pesticides Monitoring Journal, 6(3):194-228, December 1972.

PESTICIDES IN SOIL

Pesticide Residue Levels in Soils, FY 1969—National Soils Monitoring Program

G. B. Wiersma[1], H. Tai[2], and P. F. Sand[3]

ABSTRACT

This report is a summary of the FY 1969 results of the National Soils Monitoring Program, an integral part of the National Pesticide Monitoring Program (NPMP). Pesticide residues in cropland soil for 43 States and noncropland soil for 11 States are reported. Tables for each State give the number of samples collected, arithmetic means and ranges of residue levels detected, and the percent of sites with detectable residues. In addition, for selected pesticides and various States and State groupings, a frequency distribution of pesticide residues was determined. Use records for FY 1969 are given by the pesticides used, the percent of sites treated, the average application rates, and the average amounts applied per site. Comparisons are made between residue levels in different land-use areas.

Introduction

The National Soils Monitoring Program is an integral part of the National Pesticide Monitoring Program (NPMP), which was initiated as a result of a recommendation made by the President's Science Advisory Committee in its report of 1964 entitled "Use of Pesticides" that the appropriate Federal agencies "develop a continuing network to monitor residue levels in air, water, soil, man, wildlife, and fish." The NPMP as originally designed was described in the first issue of the *Pesticides Monitoring Journal* (*1*), and a revised description to reflect certain program realignments and other changes was published in the June 1971 issue of this *Journal* (*2*).

The objectives of the NPMP are to determine levels and trends of pesticides in the various components of the environment (*2*). The establishment of baseline or background levels of pesticide residues through the NPMP will provide a basis for comparison of subsequently identified pesticide residue levels in an environmental component.

The Panel on Pesticides Monitoring of the Working Group on Pesticides (*2*) listed five bases for concern to be used in evaluating pesticide residue levels in the various environmental components. They are:

(1) any concentration of a pesticide known to be potentially harmful;
(2) increasing trends;
(3) exceeding standards;
(4) recognition of adverse effects on humans; and
(5) erratic variability (a statistically oriented observation that is potentially common to each stratum sampled).

The results of this study serve to establish a baseline of pesticide residues in cropland and noncropland soils at a particular point in time (FY 1969). The present data and all future data will be evaluated using applicable criteria included in the five bases of concern outlined above.

Sampling Procedures and Methods

In general, sampling techniques involved in this study were the same as those described by Wiersma, Sand, and Cox (*3*).

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In FY 1969, cropland soil was sampled in every State except Alaska, Hawaii, Kansas, Minnesota, Montana, Oregon, and Texas. Noncropland was sampled in 11 States—Arizona, Georgia, Idaho, Iowa, Maine, Maryland, Nebraska, Virginia, Washington, West Virginia, and Wyoming. Samples collected in FY 1969 included both soil and mature crops and/or those ready for harvest; however, results of crop analyses are not published in this report.

Analytical Procedures

ORGANOCHLORINE AND ORGANOPHOSPHOROUS COMPOUNDS

A subsample of soil weighing 300 g, wet weight, was placed in a 2-qt fruit jar with 600 ml of 3:1 hexane-isopropanol solvent. The jars were sealed and rotated for 4 hours. After rotation, the soil was allowed to settle, and 200 ml of the extract solution was filtered into a 500-ml separatory funnel. Isorpropanol was removed with two washings of distilled water, and the remaining solution was then filtered through a funnel containing glass wool and anhydrous sodium sulfate (Na_2SO_4). Further cleanup was normally not required before analysis.

Gas-Liquid Chromatography

Analyses were performed on gas chromatographs equipped with tritium foil electron affinity detectors for organochlorine compounds and thermionic or flame photometric detectors for organophosphorous compounds. A dual-column system employing polar and nonpolar columns was utilized to identify and confirm pesticides. Instrument parameters were as follows:

Columns:	Glass, 183 cm long by 6 mm, o.d., and 4 mm, i.d., with one of the following packings: 3% DC-200 on 100/120 mesh Gas Chrom Q or 9% QF-1 on 100/120 mesh Gas Chrom Q
Carrier gas:	5% methane-argon at a flow rate of 80 ml/min
Temperatures:	Detector 200° C Injection port 250° C Column QF-1 166° C Column DC-200 170°-175° C

When necessary, confirmation of residues was made by thin layer chromatography or p-values. The lower limit of detection was 0.01 ppm. The average recovery rate for all pesticides was 100% (with a ±10% error); the data were corrected for recovery and also adjusted to a dry-weight basis by determining the moisture content on a separate portion of each sample using the oven drying method.

ATRAZINE

After a 4-hour Soxhlet extraction of a 50-g subsample of soil with 25 ml of water and 300 ml of methanol, the sample extract was transferred to a 1-liter separatory funnel and 200 ml of water added. The sample extract was partitioned three times with a portion of 150 ml of freon 113 for each partitioning. The freon 113 fractions were combined and concentrated to incipient dryness. The sample was then dissolved in hexane, adjusted to a 5-ml volume, and injected into a gas-liquid chromatograph.

Gas-Liquid Chromatography

A thermionic flame detector with rubidium sulfate coating on a helix coil was used. Instrument parameters were as follows:

Column:	Glass, 183 cm long by 6 mm, o.d., and 4 mm. i.d., packed with 3% Versamid 900 on 100/120 mesh Gas Chrom Q
Carrier gas:	Helium
Detector fuel gas:	Oxygen (200-300 ml/min); Hydrogen (20-30 ml/min)
Temperatures:	Detector 240° C Injection port 240° C Column 240° C

Confirmation was made using a DC-200 column at 180° C and a Coulson detector (reductive mode) at the following temperature settings: pyrolysis tube—850° C, transfer line—220° C, and block—220° C.

The minimum detection limit was 0.01 ppm, and recovery was about 100%.

2,4-D

Analyses were made following the procedure developed by Woodham *et al.* (*4*). The analytical method involved a diethyl ether extraction of acidified soil, an alkali wash to remove interfering substances, and an esterification procedure using 10% boron trichloride in 2-chloroethanol reagent. The 2-chloroethyl ester of 2,4-D was then analyzed by gas chromatography. The minimum detection limit was 0.01 ppm, and the average recovery was 85%. Results were corrected for percent recovery.

ARSENIC

Arsenic was determined by atomic absorption spectrophotometry. The soil sample was first extracted with 9.6N hydrochloric acid (HCL) and reduced to trivalent arsenic with stannous chloride. The trivalent arsenic was partitioned from HCL solution to benzene, then further partitioned into water for the absorption measurement. A Perkin-Elmer Model 303 instrument was used, and absorbance was measured with an arsenic lamp at 1972 Å with argon as an aspirant to an air-hydrogen flame. The minimum detection limit was 0.1 ppm, and the recovery value for arsenic averaged 70%. Results were corrected for percent recovery.

Results

The data in this report are for soils only (both cropland and noncropland) and include results for all States sampled in the study. Caution should be exercised when interpreting the arithmetic means presented in the tables, because pesticide residue data are not normally distributed, and the arithmetic means for pesticide residues tend to be greater than the corresponding median. Therefore, they cannot be considered an indication of the central tendency of the data. Information accompanying the arithmetic means in this report such as the percent occurrence, range of detected residues, and number of observations can aid in evaluating the arithmetic mean.

RESIDUES—ALL STATES

Table 1 presents a summary of pesticide residues in cropland soils for all 43 States sampled. Percent occur-

TABLE 1.—*Summary of pesticide residues in cropland soil from 43 States—FY 1969*

Compound	Number of Samples Analyzed[1]	Number of Positive Samples	Percent Positive Sites[2]	Mean Residue Level (ppm)	Range of Detected Residues (ppm)
Aldrin	1,729	189	10.9	0.02	0.01-3.06
Arsenic	1,726	1,713	99.3	6.43	0.25-107.45
Atrazine	199	28	14.1	0.01	0.01-1.55
Carbophenothion	66	1	1.5	<0.01	0.23
Chlordane	1,729	151	8.7	0.04	0.01-6.30
2,4-D	188	3	1.6	<0.01	0.01-0.03
DCPA (Dacthal®)	1,729	1	0.1	<0.01	0.54
o,p'-DDE	1,729	79	4.6	<0.01	0.01-0.20
p,p'-DDE	1,729	429	24.8	0.06	0.01-6.99
o,p'-DDT	1,729	243	14.1	0.03	0.01-6.29
p,p'-DDT	1,729	384	22.2	0.17	0.01-35.92
DDTR	1,729	451	26.1	0.31	0.01-78.36
DEF	1,729	1	0.1	<0.01	0.12
Diazinon	66	2	3.0	<0.01	0.02-0.15
Dicofol	1,729	9	0.5	<0.01	0.03-1.07
Dieldrin	1,729	480	27.8	0.03	0.01-1.60
Endosulfan (I)	1,729	5	0.3	<0.01	0.01-0.24
Endosulfan (II)	1,729	9	0.5	<0.01	0.01-0.53
Endosulfan sulfate	1,729	11	0.6	<0.01	0.01-0.94
Endrin	1,729	39	2.3	<0.01	0.01-0.56
Endrin aldehyde	1,729	1	0.1	<0.01	0.03
Endrin ketone	1,729	9	0.5	<0.01	0.01-0.13
Ethion	66	1	1.5	<0.01	0.03
Heptachlor	1,729	6[illegible]	3.9	<0.01	0.01-0.97
Heptachlor epoxide	1,729	139	8.0	<0.01	0.01-1.08
Isodrin	1,729	11	0.6	<0.01	0.01-0.03
Lindane	1,729	15	0.9	<0.01	0.01-0.35
Malathion	66	2	3.0	0.01	0.04-0.36
Methoxychlor	1,729	1	0.1	<0.01	0.28
Ethyl parathion	66	7	10.6	0.06	0.01-3.01
PCNB	1,729	1	0.1	<0.01	0.69
o,p'-TDE	1,729	49	2.8	0.01	0.01-4.52
p,p'-TDE	1,729	265	15.3	0.05	0.01-31.43
Toxaphene	1,729	73	4.2	0.07	0.10-11.72
Trifluralin	1,729	60	3.5	<0.01	0.01-0.25

[1] One sample per site.

[2] Percent based on number of sites with residues greater than or equal to the sensitivity limits.

rence of residues is based on the number of sites with residues greater than or equal to the sensitivity limit.

The data for atrazine, 2,4-D, and the organophosphates are not truly comparable with those determined for the organochlorines or arsenic, because analyses for atrazine and 2,4-D were made only when use records indicated that they had been applied—199 and 188 times, respectively, and analyses for organophosphates were performed on only 66 of the 1,729 samples.

Elemental arsenic residues were found most frequently, with 99.3% of the sites having detectable residues and a mean level of 6.4 ppm. It is probable that most of this arsenic was from natural sources, although agricultural sources cannot be ruled out at this time.

The most widely distributed organochlorine pesticide was dieldrin, with 27.8% of the sites having detectable residues, followed by DDTR residues (a compilation of all members of the DDT group) found at 26.1% of the sites; aldrin, found at 10.9%; and chlordane, found at 8.7%. DDTR had the highest mean residue level, with 0.31 ppm found in cropland soils. With the exception of individual members of the DDT group, the other organochlorines had average residues ranging from <0.01 to 0.07 ppm.

Based on the 66 samples analyzed for organophosphates, ethyl parathion was detected 10.6% of the time, with a mean residue level of 0.06 ppm. Malathion and diazinon were each detected 3.0% of the time, with mean residue levels of 0.01 and <0.01 ppm, respectively.

In the 188 samples analyzed for 2,4-D and other chlorophenoxy herbicides, 2,4-D was the only one detected; 2,4-D was found in 1.6% of 188 samples analyzed, with a mean residue level of <0.01 ppm. Atrazine was detected in 14.1% of the 199 samples analyzed, with a mean residue level of 0.01 ppm—the highest mean residue of the herbicides detected. Trifluralin was detected in 3.5% of the 1,729 samples, with a mean residue level of <0.01 ppm.

The residues found in noncropland soils for the 11 States sampled are presented in Table 2. The mean arsenic residue level was 5.0 ppm, occurring in 98.5% of the samples. DDTR was detected in 16.1% of the noncropland soils at levels ranging from 0.01 to 0.62 ppm, with a mean level of 0.01 ppm. With the exception of members of the DDT group, dieldrin was the most widely distributed pesticide, occurring in 4.0% of the samples, with residues ranging between 0.01 to 0.09 ppm and a mean residue level of <0.01 ppm.

RESIDUES—INDIVIDUAL STATES

The pesticide residue summaries for cropland by individual States are given in Table 3, and similar results are shown for noncropland in Table 4. It would be impractical to attempt to comment on the results for each State; therefore, in order to facilitate summarizing the data, Figs. 1, 2, and 3 are presented. These are for three of the most commonly occurring residues—arsenic, DDTR, and dieldrin. Means for each pesticide in each State were calculated, and distribution of these averages are indicated on the corresponding Figures.

TABLE 2.—*Summary of pesticide residues in noncropland soil from 11 States—FY 1969*

COMPOUND	NUMBER OF SAMPLES ANALYZED [1]	NUMBER OF POSITIVE SAMPLES	PERCENT POSITIVE SITES [2]	MEAN RESIDUE LEVEL (PPM)	RANGE OF DETECTED RESIDUES (PPM)
Aldrin	199	1	0.5	<0.01	0.02
Arsenic	198	195	98.5	5.01	0.33-54.17
Chlordane	199	3	1.5	<0.01	0.04-0.50
o,p'-DDE	199	1	0.5	<0.01	0.02
p,p'-DDE	199	27	13.6	0.01	0.01-0.31
o,p'-DDT	199	7	3.5	<0.01	0.01-0.05
p,p'-DDT	199	18	9.1	0.01	0.01-0.23
DDTR	199	32	16.1	0.01	0.01-0.62
Dicofol	199	2	1.0	<0.01	0.10-0.29
Dieldrin	199	8	4.0	<0.01	0.01-0.09
Heptachlor epoxide	199	2	1.0	<0.01	0.01
p,p'-TDE	199	6	3.0	<0.01	0.01-0.18
Toxaphene	199	1	0.5	<0.01	0.52

[1] One sample per site.
[2] Percent based on number of sites with residues greater than or equal to the sensitivity limits.

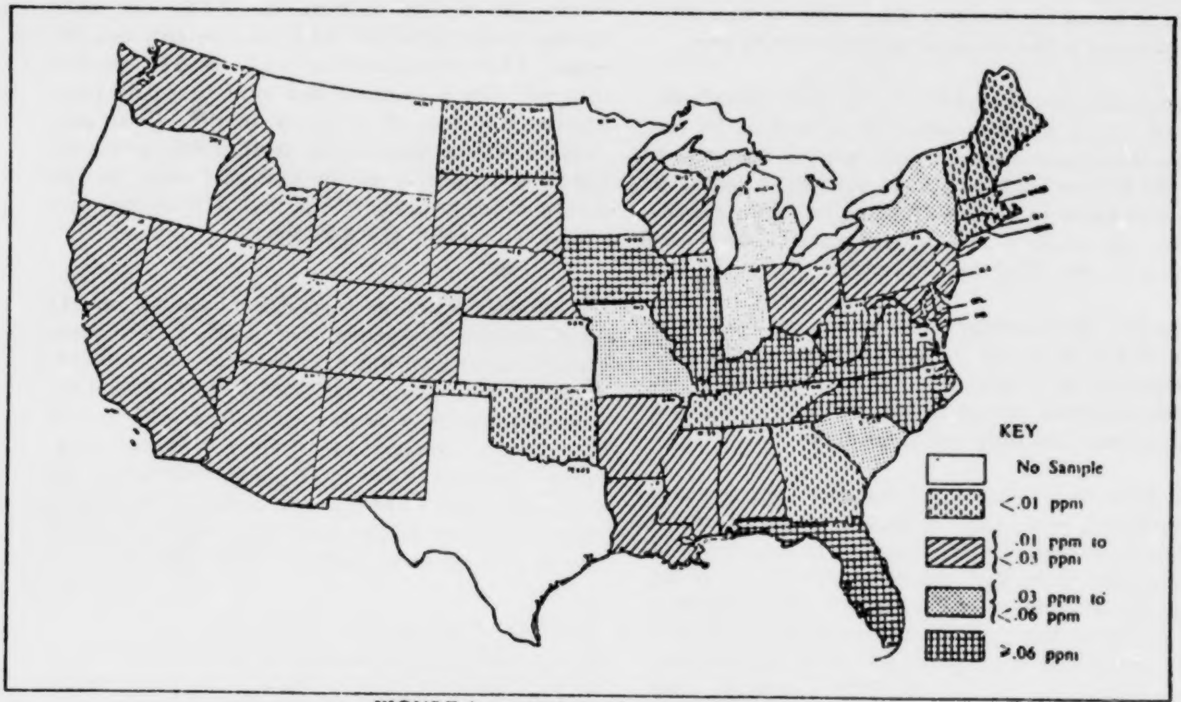

FIGURE 1.—*Arsenic residues in cropland soil*

The class intervals for the keys accompanying each Figure were obtained in the following manner: The range of residues for the Nation was obtained, and the highest value was converted to a logarithm. This value was then divided by the number of desired classes. The resulting intervals were added to obtain the class boundaries which, in turn, were converted to the untransformed dimensions. Essentially, this took advantage of the fact that most residue data are logarithmically distributed.

Distribution of arsenic residues across the United States is presented in Fig. 1. The highest residue levels were found in the New England States (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont), Arkansas, Kentucky, New York, North Dakota, Ohio, and Pennsylvania; these individual States and the New England States had mean residues of arsenic >8.4 ppm. The remaining residues were distributed primarily in the 2.0 to 8.4 ppm range, with Wyoming and Florida having less than 2.0 ppm. Those States left blank were not sampled.

The distribution of DDT residues (DDTR) is shown in Fig. 2. Once again, the key indicates the range of residues for each of the class intervals. A similar map for dieldrin residues is presented in Fig. 3.

The mean residue levels, the percent positive sites, and the range of residue levels for the 12 States with the highest arsenic residues are shown in Table 5.

Residue data for the five States with the highest DDTR residues are presented in Table 6. Although Michigan had a mean residue of 2.09 ppm and a range of 0.01 to 78.36 ppm, only 23.5% of the samples had detectable residues, indicating that the residues were not widely distributed. By contrast, Mississippi had a mean residue of 2.06 ppm with 89.7% of its sites having detectable residues and a narrower range (0.03 to 13.14 ppm). Although the range was narrower, pesticide residues were more widely distributed in Mississippi than in Michigan.

The seven States wth the highest dieldrin residues are listed in Table 7. The highest mean residue level, 0.11 ppm, was found in Illinois, with 61.3% of the sites having detectable residues. In general, the other six States tended to have mean residues approximating one another, 0.06, 0.07, or 0.08 ppm.

PESTICIDE USE RECORDS

When soil samples were collected, an attempt was made to determine what pesticides had been used on the sites for the year of sampling. The summary tables for the use records show the percent of times a pesticide was

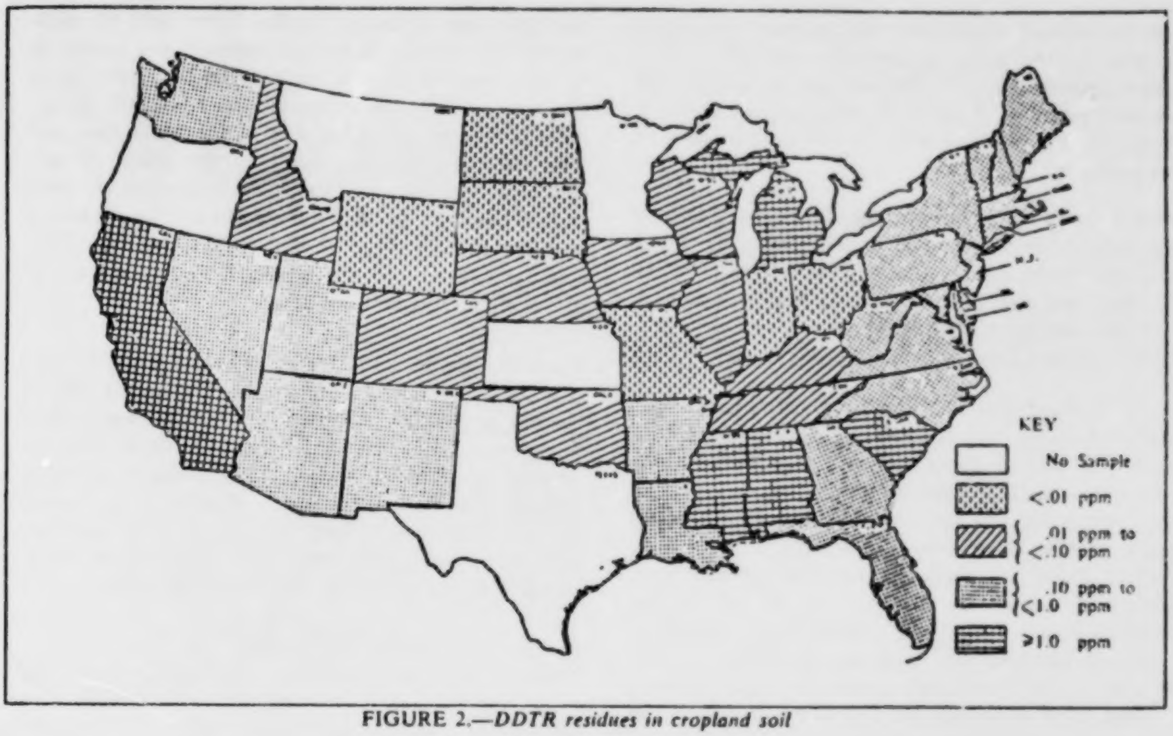
KEY
No Sample
<.01 ppm
.01 ppm to <.10 ppm
.10 ppm to <1.0 ppm
≥1.0 ppm
N.J.

FIGURE 2.—*DDTR residues in cropland soil*

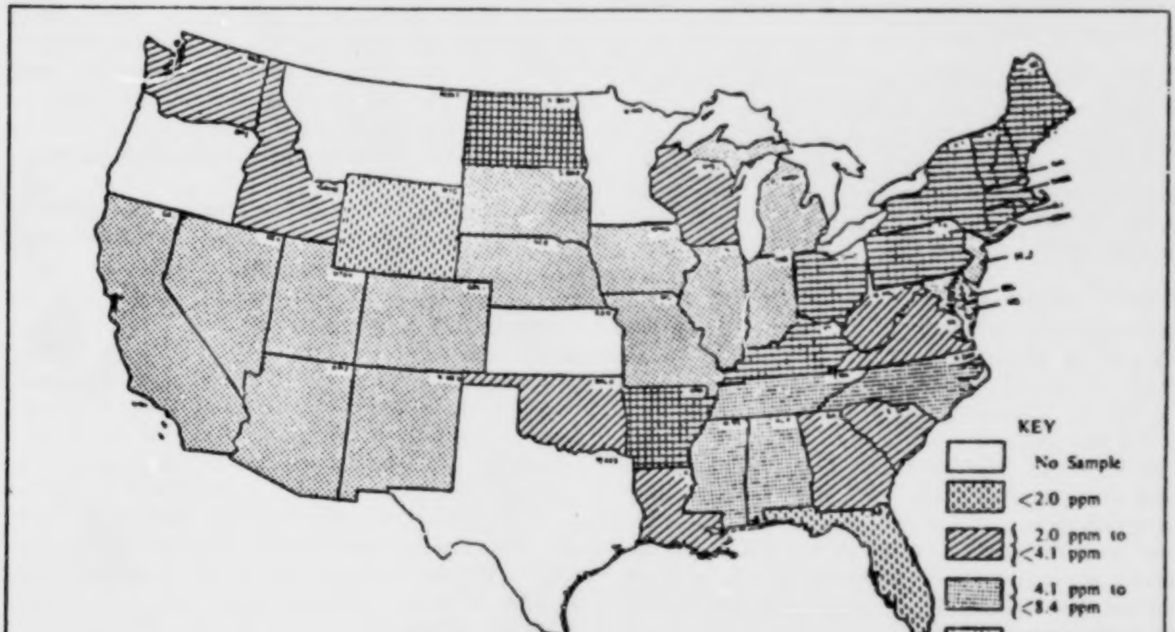
KEY
No Sample
<2.0 ppm
2.0 ppm to <4.1 ppm
4.1 ppm to <8.4 ppm
≥8.4 ppm
N.J.

FIGURE 3.—*Dieldrin residues in cropland soil*

used, the average application rate expressed in pounds per acre of the active ingredients, and the average amount applied per site. The average amount per site was determined by dividing the total amount of active ingredient of a pesticide used by the total number of sites surveyed.

Table 8 shows 130 different pesticides reported to have been used on cropland in the year of sampling. Those most commonly used were atrazine, captan, 2,4-D, malathion, and methylmercury dicyandiamide. Technical DDT was used on 3.44% of the sites, aldrin on 4.16% of the sites, and dieldrin on 1.19% of the sites.

On noncropland sites 2,4-D, malathion, and mirex were reported to have been used (Table 9). However, these should not be considered the only pesticides used on noncropland sites. In general, records of treatment of noncropland sites are less accurate than those kept for cropland. The breakdown of pesticide usage by individual States for cropland and noncropland soils, respectively, are shown in Tables 10 and 11. Of the 43 States with cropland soil analyzed, use records for 4 showed no pesticides used on the sampling sites: Nevada (2 sites); New Hampshire (2 sites); Vermont (5 sites); and Wyoming (17 sites). Of the 11 States with noncropland soil analyzed, 8 reported no pesticides used on the sampling sites: Arizona (43 sites); Iowa (7 sites); Maine (11 sites); Maryland (3 sites); Virginia (14 sites); Washington (11 sites); West Virginia (9 sites); and Wyoming (37 sites).

Because of the number of States and pesticides presented in Tables 10 and 11, it is difficult to make all possible comparisons between the use patterns indicated and the detected residues shown in Tables 3 and 4. Therefore, comparisons have been restricted to those States having the highest residues as shown in Figs. 1, 2, and 3 (arsenic, DDTR, and dieldrin, respectively).

Table 12 compares those States having the highest arsenic residues with the average amount applied per site and the percent of sites which reported using an arsenic compound. The amount of arsenic applied did not seem to be directly related to the amount detected in the soil. Arkansas, Kentucky, North Dakota, and Ohio reportedly used no arsenic compounds, whereas New England, New York, and Pennsylvania reported using sodium arsenite and lead arsenate. The application rates were below the detected residue levels, and the percent of times used was below the percent of times residues were detected. It also must be considered that the application rates were for the active ingredients of sodium arsenite and lead arsenate, and not for elemental arsenic alone. A fair assumption would be that most arsenic residues detected in cropland soils probably resulted from natural levels of arsenic.

A similar comparison for the five States with the highest DDTR residues is found in Table 13. It is interesting to note that use records for four of the States listed (California, Michigan, Mississippi, and South Carolina) indicate that the amount applied was less than the mean level detected in the soil. Also, in all five States, the percent of sites positive for DDTR was approximately three or four times greater than the percent of sites reportedly treated with DDT. Unlike arsenic, the residues of DDTR could only result from the use of DDT either in the year of sampling or in previous years.

Table 14 lists the seven States with the highest dieldrin residues. In most cases, the average amount of aldrin/dieldrin applied approximated the mean residue of dieldrin detected in the soil, but the percent of sites reportedly treated with dieldrin or aldrin was always considerably less than the percent of sites with dieldrin residues. This wider distribution of dieldrin residues, when compared to use records for the year of sampling, probably indicates residues from previous years.

PESTICIDE FREQUENCY DISTRIBUTION

The statistics discussed thus far, namely the mean, the range, and the percent of sites at which residues were detected, do not describe their distribution. To describe this distribution, probit analysis was used. The residue levels were ranked from lowest to highest, accumulated, and the percentages computed. The residues were transformed to logarithms, the percentages to probits, and the relationship between the logarithms of the residues and the probits of the accumulated percentages was calculated by regression analysis. The computer program used was that of Daum. (5); the theory and techniques as applied in the cited reference were modified slightly.

The residue levels at the fiftieth percentile point (median) for the individual pesticides in soil for each State along with the upper and lower 95% fiducial limits are presented in Table 15. For example, in the State of Alabama, the fiftieth percentile point (median) for arsenic was 4.09 ppm. Thus, 50% of the sites had residues less than 4.09 ppm. The upper and the lower fiducial limits of the residues establish the 95% confidence interval about the residue value for the fiftieth percentile. It should be noted that the mean for a particular State is not the same as the fiftieth percentile point (median) from the frequency distribution. For example, the mean level of arsenic for Alabama was 6.1 ppm, while the frequency distribution indicated 4.09 ppm for the fiftieth percentile point. This is an example of the fact that residue data are not normally distributed and the mean and median are not identical.

Not all pesticides are shown for all States. A cutoff point of six or more pairs of observations was used to eliminate situations where there were too few observations to calculate a reliable distribution. Space did not permit printing tables showing distribution of pesticide residues for percentiles other than the fiftieth.

CROPPING REGIONS ANALYSIS

The data were grouped by counties into various cropping regions, and these are shown in Tables 16 and 17. The boundaries for the various cropping areas were based on a major land-use map of the United States compiled by F. J. Marschner of the U.S. Department of Agriculture, Bureau of Agricultural Economics, 1950. No effort was made to make a land-use division within counties. This resulted in a good definition of the larger land-use areas such as the corn belt and cotton-growing areas. The land in the United States was grouped into several major land-use areas—corn, cotton, general farming, hay, small grain, vegetables, and fruit. In some cases, two areas overlapped. Irrigated land was determined from information obtained at the time of sample collection in this study.

It is of interest to make a few individual comparisons between the cropping regions and the national means. For example, note that in the corn region, aldrin occurred 23.5% of the time (Table 17) with a mean residue level of 0.05 ppm (Table 16). However, nationally, aldrin only occurred 10.9% of the time with a mean level of 0.02 ppm (Table 1), an indication of the heavier use of aldrin in the corn region. But, in the corn region, the mean residue level of DDTR was 0.14 ppm which is well below the national mean of 0.31 ppm.

The vegetable and fruit cropping region had the highest level of DDTR, over two times higher than the next highest cropping region and over six times higher than the national mean for DDTR. This might result from a high use of DDT in various orchard operations. The next highest residue was found in the cotton and vegetable region, with approximately equal amounts detected between them. The rest of the amounts of DDT in the cotton and general farming, general farming, hay and general farming, and irrigated land were similar to one another. The two areas with the least amount of DDTR in the soil were the corn and small grains cropping regions.

The corn, vegetable, and vegetable and fruit cropping regions had the heaviest residues of dieldrin. Residues of dieldrin in the other cropping regions were either equal to or below the mean residues detected for all States (Table 1).

The cotton cropping region had the highest toxaphene residues. The cotton and general farming and general farming cropping regions had residue levels of about half those detected in the cotton cropping region.

Acknowledgment

It is not possible to list, by name, all the people who contributed to this study; however, special mention is made of the staff at the Monitoring Laboratory, Mississippi Test Facility, Bay St. Louis, Miss., who processed and analyzed the samples for chemical residues and contributed immeasurably to this study and of the inspectors from the Animal Plant Health Inspection Service (APHIS) who collected the samples. Finally, recognition is due Dr. Edwin Cox, Biometrical Services Staff, USDA, for the sample allocation procedures and to Dr. Richard Daum of the Animal Plant Health Inspection Service, USDA, for the probit analyses.

See Appendix for chemical names and compounds discussed in this paper.

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TABLE 3.—*Pesticide residues in cropland soil from 43 States—FY 1969*

Compound	Number of Samples Analyzed [1]	Number of Positive Samples	Percent Positive Sites [2]	Mean Residue Level (ppm)	Range of Detected Residues (ppm)
ALABAMA					
Arsenic	23	23	100.0	6.11	0.70-28.60
Chlordane	22	3	13.6	0.04	0.07-0.62
o,p'-DDE	22	1	4.6	<0.01	0.01
p,p'-DDE	22	19	86.4	0.17	0.01-0.72
o,p'-DDT	22	16	72.7	0.09	0.01-0.65
p,p'-DDT	22	20	90.9	0.78	0.02-6.60
DDTR	22	20	90.9	1.13	0.05-8.08
Dieldrin	22	5	22.7	0.01	0.01-0.14
Endrin	22	2	9.1	<0.01	0.03-0.05
Heptachlor	22	2	9.1	<0.01	0.01
Heptachlor epoxide	22	3	13.6	<0.01	0.01-0.04
Lindane	22	2	9.1	<0.01	0.01
o,p'-TDE	22	1	4.6	<0.01	0.08
p,p'-TDE	22	13	59.1	0.07	0.01-0.73
Toxaphene	22	6	27.3	0.69	0.68-4.95
Trifluralin	22	7	31.8	0.01	0.01-0.08
ARIZONA					
Arsenic	8	8	100.0	6.58	2.82-9.97
o,p'-DDE	8	4	50.0	0.02	0.01-0.07
p,p'-DDE	8	8	100.0	0.46	0.06-0.84
o,p'-DDT	8	5	62.5	0.07	0.08-0.17
p,p'-DDT	8	7	87.5	0.20	0.03-0.57
DDTR	8	8	100.0	0.76	0.06-1.56
Endosulfan (I)	8	1	12.5	0.03	0.24
Endosulfan (II)	8	1	12.5	0.07	0.53
Endosulfan sulfate	8	1	12.5	0.04	0.29
Endrin	8	3	37.5	0.07	0.10-0.22
Endrin ketone	8	2	25.0	0.01	0.01-0.07
p,p'-TDE	8	2	25.0	0.01	0.03-0.06
Toxaphene	8	6	75.0	1.09	0.57-4.27
Trifluralin	8	1	12.5	0.02	0.13
ARKANSAS					
Aldrin	47	7	14.9	<0.01	0.01-0.06
Arsenic	47	47	100.0	8.98	1.70-28.25
o,p'-DDE	47	5	10.6	0.01	0.01-0.07
p,p'-DDE	47	32	68.1	0.24	0.01-2.81
o,p'-DDT	47	22	46.8	0.07	0.01-1.11
p,p'-DDT	47	32	68.1	0.29	0.01-3.28
DDTR	47	34	72.3	0.67	0.03-7.20
Dieldrin	47	12	25.5	0.02	0.01-0.24
Endrin	47	5	10.6	0.01	0.01-0.29
Endrin ketone	47	2	4.3	<0.01	0.10-0.13
p,p'-TDE	47	27	57.5	0.07	0.01-1.19
Toxaphene	47	8	17.0	0.27	0.32-3.40
Trifluralin	47	4	8.5	0.01	0.01-0.20
CALIFORNIA					
Aldrin	65	1	1.5	<0.01	0.03
Arsenic	65	65	100.0	5.15	0.74-23.67
Carbophenothion	17	1	5.9	0.01	0.23
Chlordane	65	2	3.1	0.01	0.10-0.32
DCPA	65	1	1.5	0.01	0.54
o,p'-DDE	65	24	36.9	0.01	0.01-0.14

TABLE 3.—*Pesticide residues in cropland soil from 43 States—FY 1969*—Continued

Compound	Number of Samples Analyzed [1]	Number of Positive Samples	Percent Positive Sites [2]	Mean Residue Level (ppm)	Range of Detected Residues (ppm)
CALIFORNIA—Continued					
p,p'-DDE	65	55	84.6	0.37	0.01-5.93
o,p'-DDT	65	32	49.2	0.08	0.01-1.33
p,p'-DDT	65	48	73.9	0.54	0.01-11.09
DDTR	65	55	84.6	1.47	0.01-41.81
Diazinon	17	1	5.9	<0.01	0.02
Dicofol	65	6	9.2	0.02	0.03-1.07
Dieldrin	65	20	30.8	0.02	0.01-0.31
Endosulfan (I)	65	1	1.5	<0.01	0.01
Endosulfan (II)	65	5	7.7	<0.01	0.01-0.09
Endosulfan sulfate	65	5	7.7	0.01	0.02-0.15
Endrin	65	9	13.9	0.01	0.01-0.16
Heptachlor epoxide	65	8	12.3	<0.01	0.01-0.03
Lindane	65	2	3.1	<0.01	0.02
Ethyl parathion	17	1	5.9	<0.01	0.02
o,p'-TDE	65	13	20.0	0.09	0.01-4.52
p,p'-TDE	65	40	61.5	0.38	0.01-20.13
Toxaphene	65	10	15.4	0.16	0.16-2.07
Trifluralin	65	7	10.8	<0.01	0.01-0.10
COLORADO					
Aldrin	60	1	1.7	<0.01	0.02
Arsenic	58	58	100.0	4.60	1.78-9.46
p,p'-DDE	60	7	11.7	0.01	0.01-0.17
o,p'-DDT	60	2	3.3	<0.01	0.01-0.03
p,p'-DDT	60	5	8.3	0.01	0.01-0.22
DDTR	60	8	13.3	0.01	0.01-0.42
Dieldrin	60	5	8.3	0.01	0.01-0.61
Endrin	60	3	5.0	<0.01	0.01-0.02
Endrin ketone	60	1	1.7	<0.01	0.05
p,p'-TDE	60	1	1.7	<0.01	0.01
CONNECTICUT					
Arsenic	2	2	100.0	3.96	2.33-5.59
p,p'-DDE	2	1	50.0	0.01	0.01
p,p'-DDT	2	1	50.0	0.03	0.05
DDTR	2	1	50.0	0.03	0.06
Dieldrin	2	1	50.0	0.01	0.01
DELAWARE					
Arsenic	3	3	100.0	2.97	0.95-5.88
p,p'-DDE	3	1	33.3	<0.01	0.01
DDTR	3	1	33.3	<0.01	0.01
Dieldrin	3	1	33.3	<0.01	0.01
FLORIDA					
Aldrin	18	1	5.6	0.03	0.47
Arsenic	18	16	88.9	0.77	0.25-3.08
Chlordane	18	9	50.0	0.36	0.04-3.32
o,p'-DDE	18	2	11.1	0.01	0.03-0.06
p,p'-DDE	18	13	72.2	0.25	0.01-2.40
o,p'-DDT	18	9	50.0	0.10	0.01-0.98
p,p'-DDT	18	14	77.8	0.37	0.01-2.08
DDTR	18	14	77.8	0.85	0.01-5.03

TABLE 3.—*Pesticide residues in cropland soil from 43 States—FY 1969*—Continued

Compound	Number of Samples Analyzed[1]	Number of Positive Samples	Percent Positive Sites[2]	Mean Residue Level (ppm)	Range of Detected Residues (ppm)
FLORIDA—Continued					
Diazinon	5	1	20.0	0.03	0.15
Dieldrin	18	7	38.9	0.08	0.01-0.52
Endrin	18	2	11.1	0.03	0.13-0.38
Endrin aldehyde	18	1	5.6	<0.01	0.03
Endrin ketone	18	1	5.6	<0.01	0.03
Ethion	5	1	20.0	0.01	0.03
Heptachlor	18	1	5.6	<0.01	0.05
Heptachlor epoxide	18	3	16.7	0.01	0.01-0.07
Ethyl parathion	5	2	40.0	0.60	0.01-3.01
o,p'-TDE	18	1	5.6	0.02	0.34
p,p'-TDE	18	11	61.1	0.11	0.01-0.64
Toxaphene	18	2	11.1	0.08	0.62-0.77
Trifluralin	18	1	5.6	<0.01	0.03
GEORGIA					
Arsenic	29	29	100.0	2.61	0.37-10.72
Chlordane	22	1	4.6	0.01	0.19
2,4-D	3	1	33.3	<0.01	0.01
o,p'-DDE	22	5	22.7	0.01	0.01-0.08
p,p'-DDE	22	20	90.9	0.16	0.01-1.04
o,p'-DDT	22	13	59.1	0.09	0.01-0.73
p,p'-DDT	22	18	81.8	0.56	0.01-4.64
DDTR	22	21	95.5	0.96	0.01-6.31
DEF	22	1	4.6	0.01	0.12
Dieldrin	22	4	18.2	<0.01	0.01-0.03
Endrin	22	1	4.6	0.02	0.42
Heptachlor epoxide	22	1	4.6	<0.01	0.02
PCNB	22	1	4.6	0.03	0.69
o,p'-TDE	22	1	4.6	0.02	0.34
p,p'-TDE	22	15	68.2	0.10	0.01-1.21
Toxaphene	22	8	36.4	0.60	0.43-5.63
Trifluralin	22	3	13.6	<0.01	0.02-0.04
IDAHO					
Arsenic	33	32	97.0	3.22	0.47-8.58
Chlordane	33	2	6.1	<0.01	0.03-0.07
p,p'-DDE	33	8	24.2	0.01	0.01-0.09
o,p'-DDT	33	6	18.2	0.01	0.01-0.13
p,p'-DDT	33	8	24.2	0.04	0.01-0.67
DDTR	33	8	24.2	0.07	0.02-1.03
Dieldrin	33	3	9.1	0.01	0.03-0.11
Heptachlor epoxide	33	1	3.0	<0.01	0.01
o,p'-TDE	33	3	9.1	<0.01	0.01
p,p'-TDE	33	6	18.2	0.01	0.01-0.15
Trifluralin	33	2	6.1	0.01	0.01-0.24
ILLINOIS					
Aldrin	142	60	42.3	0.13	0.01-2.24
Arsenic	142	142	100.0	8.05	1.54-33.40
Atrazine	43	2	4.7	<0.01	0.02-0.10
Chlordane	142	36	25.4	0.23	0.02-5.20
p,p'-DDE	142	16	11.3	<0.01	0.01-0.05
o,p'-DDT	142	4	2.8	<0.01	0.01-0.02
p,p'-DDT	142	12	8.5	<0.01	0.01-0.06
DDTR	142	16	11.3	0.01	0.01-0.29

TABLE 3.—*Pesticide residues in cropland soil from 43 States—FY 1969*—Continued

Compound	Number of Samples Analyzed [1]	Number of Positive Samples	Percent Positive Sites [1]	Mean Residue Level (ppm)	Range of Detected Residues (ppm)
ILLINOIS—Continued					
Dieldrin	142	87	61.3	0.11	0.01-1.42
Heptachlor	142	31	21.8	0.03	0.01-0.59
Heptachlor epoxide	142	36	25.4	0.02	0.01-1.08
Isodrin	142	2	1.4	<0.01	0.02
o,p'-TDE	142	1	0.7	<0.01	0.06
p,p'-TDE	142	5	3.5	<0.01	0.01-0.16
Trifluralin	142	2	1.4	<0.01	0.05-0.16
INDIANA					
Aldrin	78	13	16.7	0.07	0.01-3.06
Arsenic	78	78	100.0	7.88	1.28-19.65
Chlordane	78	4	5.1	0.02	0.07-0.53
p,p'-DDE	78	1	1.3	<0.01	0.03
o,p'-DDT	78	2	2.6	<0.01	0.01-0.03
p,p'-DDT	78	2	2.6	<0.01	0.02-0.09
DDTR	78	2	2.6	<0.01	0.06-0.14
Dieldrin	78	21	26.9	0.03	0.01-0.58
Heptachlor	78	2	2.6	<0.01	0.02-0.08
Heptachlor epoxide	78	1	1.3	<0.01	0.02
Isodrin	78	1	1.3	<0.01	0.03
p,p'-TDE	78	2	2.6	<0.01	0.01
Trifluralin	78	1	1.3	<0.01	0.03
IOWA					
Aldrin	151	48	31.8	0.04	0.01-1.37
Arsenic	152	152	100.0	7.51	0.66-107.45
Atrazine	48	13	27.1	0.05	0.01-1.55
Chlordane	151	32	21.2	0.13	0.04-6.30
p,p'-DDE	151	21	13.9	0.01	0.01-0.18
o,p'-DDT	151	6	4.0	<0.01	0.01-0.05
p,p'-DDT	151	23	15.2	0.01	0.01-0.34
DDTR	151	25	16.6	0.03	0.01-0.60
Dieldrin	151	81	53.6	0.06	0.01-0.42
Heptachlor	151	14	9.3	0.02	0.01-0.97
Heptachlor epoxide-	151	31	20.5	0.01	0.01-0.33
Isodrin	151	2	1.3	<0.01	0.01-0.02
o,p'-TDE	151	1	0.7	<0.01	0.10
p,p'-TDE	151	8	5.3	<0.01	0.01-0.50
Trifluralin	151	5	3.3	<0.01	0.02-0.08
KENTUCKY					
Aldrin	31	8	25.8	0.03	0.01-0.42
Arsenic	31	31	100.0	8.41	2.60-12.80
Chlordane	31	4	12.9	0.02	0.06-0.27
o,p'-DDE	31	1	3.2	<0.01	0.03
p,p'-DDE	31	5	16.1	0.01	0.01-0.17
o,p'-DDT	31	3	9.7	0.02	0.01-0.34
p,p'-DDT	31	6	19.4	0.04	0.02-1.00
DDTR	31	6	19.4	0.08	0.03-1.84
Dieldrin	31	17	54.8	0.06	0.01-0.65
Heptachlor	31	2	6.5	<0.01	0.01
Heptachlor epoxide	31	1	3.2	<0.01	0.02
Isodrin	31	2	6.5	<0.01	0.01
o,p'-TDE	31	1	3.2	<0.01	0.02
p,p'-TDE	31	4	12.9	0.01	0.02-0.28

TABLE 3.—*Pesticide residues in cropland soil from 43 States—FY 1969*—Continued

Compound	Number of Samples Analyzed[1]	Number of Positive Samples	Percent Positive Sites[2]	Mean Residue Level (ppm)	Range of Detected Residues (ppm)
LOUISIANA					
Aldrin	27	5	18.5	<0.01	0.01-0.02
Arsenic	27	26	96.3	2.15	0.26-6.34
Chlordane	27	1	3.7	<0.01	0.11
o,p′-DDE	27	2	7.4	<0.01	0.04-0.05
p,p′-DDE	27	12	44.4	0.19	0.01-2.55
o,p′-DDT	27	9	33.3	0.10	0.02-1.45
p,p′-DDT	27	13	48.2	0.61	0.02-7.17
DDTR	27	13	48.2	0.99	0.03-10.99
Dieldrin	27	10	37.0	0.02	0.01-0.13
Endrin	27	1	3.7	<0.01	0.06
Endrin ketone	27	1	3.7	<0.01	0.02
p,p′-TDE	27	9	33.3	0.08	0.02-1.63
Toxaphene	27	4	14.8	0.57	0.59-11.72
Trifluralin	27	1	3.7	<0.01	0.07
MAINE					
Arsenic	8	8	100.0	16.01	5.06-44.06
Chlordane	8	1	12.5	0.02	0.12
p,p′-DDE	8	6	75.0	0.12	0.02-0.36
o,p′-DDT	8	5	62.5	0.13	0.02-0.46
p,p′-DDT	8	6	75.0	0.54	0.04-1.87
DDTR	8	6	75.0	0.85	0.09-2.86
Endrin	8	1	12.5	0.02	0.15
Heptachlor	8	1	12.5	<0.01	0.01
Heptachlor epoxide	8	1	12.5	<0.01	0.01
p,p′-TDE	8	6	75.0	0.06	0.01-0.19
MARYLAND					
Arsenic	12	12	100.0	5.69	3.40-11.90
Chlordane	12	1	8.3	0.01	0.09
p,p′-DDE	12	2	16.7	<0.01	0.02
p,p′-DDT	12	1	8.3	<0.01	0.03
DDTR	12	2	16.7	0.01	0.02-0.05
Dieldrin	12	1	7.3	0.01	0.06
Heptachlor epoxide	12	1	8.3	<0.01	0.02
MASSACHUSETTS					
Arsenic	2	2	100.0	9.75	7.35-12.15
p,p′-DDE	2	1	50.0	0.17	0.34
o,p′-DDT	2	1	50.0	0.10	0.20
p,p′-DDT	2	1	50.0	0.49	0.97
DDTR	2	1	50.0	0.78	1.55
p,p′-TDE	2	1	50.0	0.02	0.04
MICHIGAN					
Aldrin	51	2	3.9	<0.01	0.01-0.10
Arsenic	52	52	100.0	4.85	0.13-11.94
Atrazine	13	1	7.7	0.01	0.18
o,p′-DDE	51	4	7.8	<0.01	0.01-0.14
p,p′-DDE	51	12	23.5	0.16	0.01-4.58
o,p′-DDT	51	3	5.9	0.18	0.15-6.29
p,p′-DDT	51	5	9.8	1.10	0.01-35.92
DDTR	51	12	23.5	2.09	0.01-78.36

TABLE 3.—*Pesticide residues in cropland soil from 43 States—FY 1969*—Continued

Compound	Number of Samples Analyzed [1]	Number of Positive Samples	Percent Positive Sites [2]	Mean Residue Level (ppm)	Range of Detected Residues (ppm)
MICHIGAN—Continued					
Dieldrin	51	11	21.6	0.05	0.01-1.01
Endosulfan (I)	51	2	3.9	0.01	0.03-0.24
Endosulfan sulfate	51	2	3.9	0.02	0.25-0.94
Endrin	51	1	2.0	<0.01	0.01
p,p'-TDE	51	5	9.8	0.65	0.02-31.43
MISSISSIPPI					
Arsenic	30	30	100.0	5.70	1.10-16.90
o,p'-DDE	29	9	31.0	0.01	0.01-0.08
p,p'-DDE	29	26	89.7	0.31	0.01-1.43
o,p'-DDT	29	22	75.9	0.20	0.02-1.35
p,p'-DDT	29	26	89.7	1.36	0.01-9.28
DDTR	29	26	89.7	2.06	0.03-13.14
Dieldrin	29	10	34.5	0.01	0.02-0.10
Endrin	29	1	3.5	0.01	0.19
Endrin ketone	29	1	3.5	<0.01	0.11
Lindane	29	2	6.9	<0.01	0.01-0.04
o,p'-TDE	29	2	6.9	0.03	0.33-0.49
p,p'-TDE	29	20	69.0	0.15	0.01-0.81
Toxaphene	29	14	48.3	0.78	0.10-8.80
Trifluralin	29	6	20.7	0.02	0.02-0.25
MISSOURI					
Aldrin	82	18	22.0	0.05	0.01-1.59
Arsenic	81	80	98.8	5.99	0.49-24.51
Chlordane	82	6	7.3	0.03	0.17-0.60
p,p'-DDE	82	3	3.7	<0.01	0.01
o,p'-DDT	82	2	2.4	<0.01	0.01-0.02
p,p'-DDT	82	3	3.7	<0.01	0.02-0.09
DDTR	82	3	3.7	<0.01	0.03-0.12
Dieldrin	82	26	31.7	0.04	0.01-0.55
Endrin	82	1	1.2	<0.01	0.01
Heptachlor	82	5	6.1	<0.01	0.01-0.04
Heptachlor epoxide	82	5	6.1	<0.01	0.01-0.06
Isodrin	82	1	1.2	<0.01	0.03
Toxaphene	82	1	1.2	0.04	3.15
Trifluralin	82	5	6.1	<0.01	0.02-0.10
NEBRASKA					
Aldrin	106	2	1.9	<0.01	0.01
Arsenic	106	106	100.0	5.81	0.33-15.80
Atrazine	72	12	16.7	<0.01	0.01-0.12
Chlordane	106	11	10.4	0.01	0.03-0.18
p,p'-DDE	106	14	13.2	0.01	0.01-0.10
o,p'-DDT	106	6	5.7	<0.01	0.01-0.08
p,p'-DDT	106	12	11.3	0.01	0.01-0.19
DDTR	106	16	15.1	0.01	0.02-0.31
Dicofol	106	2	1.9	<0.01	0.10
Dieldrin	106	37	34.9	0.02	0.01-0.19
Endrin	106	1	0.9	<0.01	0.02
Heptachlor	106	1	0.9	<0.01	0.01
Heptachlor epoxide	106	12	11.3	<0.01	0.01-0.03
Malathion	2	1	50.0	0.18	0.36
p,p'-TDE	106	4	3.8	<0.01	0.01-0.05

TABLE 3.—*Pesticide residues in cropland soil from 43 States—FY 1969*—Continued

COMPOUND	NUMBER OF SAMPLES ANALYZED [1]	NUMBER OF POSITIVE SAMPLES	PERCENT POSITIVE SITES [2]	MEAN RESIDUE LEVEL (PPM)	RANGE OF DETECTED RESIDUES (PPM)
NEVADA					
Arsenic	2	2	100.0	2.32	1.77-2.86
NEW HAMPSHIRE					
Arsenic	2	2	100.0	5.35	1.31-9.38
p,p'-DDE	2	1	50.0	0.02	0.03
DDTR	2	1	50.0	0.02	0.03
NEW JERSEY					
Arsenic	5	5	100.0	11.72	4.55-17.21
o,p'-DDE	5	1	20.0	<0.01	0.02
p,p'-DDE	5	2	40.0	0.17	0.18-0.66
o,p'-DDT	5	1	20.0	0.06	0.28
p,p'-DDT	5	2	40.0	0.24	0.05-1.17
DDTR	5	2	40.0	0.55	0.26-2.48
Dieldrin	5	2	40.0	0.05	0.05-0.21
Endosulfan (II)	5	1	20.0	<0.01	0.02
Endosulfan sulfate	5	1	20.0	0.02	0.11
Heptachlor epoxide	5	1	20.0	<0.01	0.01
Lindane	5	1	20.0	0.01	0.03
Ethyl parathion	1	1	100.0	0.02	0.02
o,p'-TDE	5	1	20.0	0.02	0.09
p,p'-TDE	5	2	40.0	0.06	0.03-0.26
NEW MEXICO					
Arsenic	10	10	100.0	4.64	0.66-15.82
p,p'-DDE	10	4	40.0	0.02	0.01-0.11
o,p'-DDT	10	1	10.0	<0.01	0.01
p,p'-DDT	10	4	40.0	0.01	0.01-0.03
DDTR	10	4	40.0	0.02	0.02-0.15
Dieldrin	10	1	10.0	<0.01	0.01
NEW YORK					
Arsenic	37	35	94.6	9.38	1.24-43.90
Chlordane	38	1	2.6	0.08	3.19
o,p'-DDE	38	3	7.9	<0.01	0.01-0.06
p,p'-DDE	38	15	39.5	0.23	0.01-3.70
o,p'-DDT	38	11	29.0	0.07	0.01-1.45
p,p'-DDT	38	13	34.2	0.53	0.02-7.67
DDTR	38	15	39.5	0.91	0.01-13.29
Dieldrin	38	13	34.2	0.05	0.01-0.96
Endrin	38	1	2.6	0.01	0.56
Endrin ketone	38	1	2.6	<0.01	0.05
Lindane	38	3	7.9	0.01	0.01-0.23
Methoxychlor	38	1	2.6	0.01	0.28
o,p'-TDE	38	2	5.3	0.01	0.06-0.37
p,p'-TDE	38	10	26.3	0.07	0.01-1.49
NORTH CAROLINA					
Aldrin	31	3	9.7	0.05	0.01-1.12
Arsenic	27	27	100.0	6.18	0.73-22.00
Chlordane	31	1	3.2	<0.01	0.11

TABLE 3.—*Pesticide residues in cropland soil from 43 States—FY 1969*—Continued

Compound	Number of Samples Analyzed[1]	Number of Positive Samples	Percent Positive Sites[2]	Mean Residue Level (ppm)	Range of Detected Results (ppm)
			NORTH CAROLINA—Continued		
o,p'-DDE	31	6	19.4	<0.01	0.01-0.03
p,p'-DDE	31	22	71.0	0.08	0.01-0.44
o,p'-DDT	31	14	45.2	0.07	0.03-0.83
p,p'-DDT	31	19	61.3	0.28	0.01-1.75
DDTR	31	22	71.0	0.53	0.02-2.88
Dieldrin	31	10	32.3	0.08	0.01-1.53
Endrin	31	2	6.5	<0.01	0.01-0.08
Heptachlor	31	2	6.5	<0.01	0.01-0.02
Heptachlor epoxide	31	4	12.9	<0.01	0.01-0.03
Isodrin	31	1	3.2	<0.01	0.01
Ethyl parathion	6	1	16.7	<0.01	0.02
o,p'-TDE	31	11	35.5	0.03	0.03-0.17
p,p'-TDE	31	19	61.3	0.07	0.01-0.27
Toxaphene	31	7	22.6	0.28	0.34-3.20
Trifluralin	31	2	6.5	<0.01	0.03-0.11
			NORTH DAKOTA		
Aldrin	157	1	0.6	<0.01	0.03
Arsenic	158	158	100.0	8.50	0.96-37.53
Chlordane	157	3	1.9	<0.01	0.03-0.15
p,p'-DDE	157	10	6.4	<0.01	0.01-0.14
o,p'-DDT	157	5	3.2	<0.01	0.01-0.19
p,p'-DDT	157	8	5.1	0.01	0.01-0.56
DDTR	157	10	6.4	0.01	0.01-0.95
Dieldrin	157	12	7.6	<0.01	0.01-0.20
Endrin	157	1	0.6	<0.01	0.01
Heptachlor epoxide	157	3	1.9	<0.01	0.02-0.07
p,p'-TDE	157	7	4.5	<0.01	0.01-0.06
			OHIO		
Aldrin	68	10	14.7	0.03	0.01-0.74
Arsenic	69	69	100.0	11.23	1.15-41.49
Chlordane	68	3	4.4	0.01	0.01-0.71
o,p'-DDE	68	1	1.5	<0.01	0.20
p,p'-DDE	68	11	16.2	0.03	0.01-1.77
o,p'-DDT	68	2	2.9	0.01	0.19-0.22
p,p'-DDT	68	6	8.8	0.04	0.01-1.27
DDTR	68	11	16.2	0.08	0.01-3.38
Dieldrin	68	19	27.9	0.02	0.01-0.30
Endosulfan (I)	68	1	1.5	<0.01	0.07
Endosulfan (II)	68	1	1.5	<0.01	0.29
Endosulfan sulfate	68	1	1.5	0.01	0.40
Heptachlor	68	2	2.9	<0.01	0.01
Heptachlor epoxide	68	1	1.5	<0.01	0.01
Isodrin	68	2	2.9	<0.01	0.01-0.03
Lindane	68	1	1.5	0.01	0.35
p,p'-TDE	68	3	4.4	<0.01	0.04-0.12
Trifluralin	68	1	1.5	<0.01	0.06
			OKLAHOMA		
Arsenic	62	60	96.8	3.30	0.24-14.58
Chlordane	64	1	1.6	<0.01	0.07
p,p'-DDE	64	10	15.6	<0.01	0.01-0.09
o,p'-DDT	64	1	1.6	<0.01	0.01
p,p'-DDT	64	9	14.1	<0.01	0.01-0.09
DDTR	64	10	15.6	0.01	0.02-0.17

TABLE 3.—*Pesticide residues in cropland soil from 43 States—FY 1969*—Continued

COMPOUND	NUMBER OF SAMPLES ANALYZED [1]	NUMBER OF POSITIVE SAMPLES	PERCENT POSITIVE SITES [2]	MEAN RESIDUE LEVEL (PPM)	RANGE OF DETECTED RESIDUES (PPM)
OKLAHOMA—Continued					
Dieldrin	64	2	3.1	<0.01	0.01
Heptachlor epoxide	64	1	1.6	<0.01	0.01
p,p'-TDE	64	2	3.1	<0.01	0.01-0.02
Trifluralin	64	1	1.6	<0.01	0.03
PENNSYLVANIA					
Arsenic	29	29	100.0	10.80	2.96-64.94
Chlordane	29	6	20.7	0.07	0.02-0.92
o,p'-DDE	29	1	3.5	<0.01	0.08
p,p'-DDE	29	9	31.0	0.07	0.01-1.52
o,p'-DDT	29	5	17.2	0.03	0.01-0.67
p,p'-DDT	29	8	27.6	0.12	0.01-2.99
DDTR	29	11	37.9	0.27	0.01-5.50
Dicofol	29	1	3.5	0.02	0.53
Dieldrin	29	10	34.5	0.02	0.01-0.14
Endosulfan (II)	29	1	3.5	<0.01	0.02
Endosulfan sulfate	29	1	3.5	<0.01	0.01
Heptachlor epoxide	29	4	13.8	<0.01	0.01-0.03
Ethyl parathion	3	1	33.3	<0.01	0.01
o,p'-TDE	29	4	13.8	0.01	0.03-0.20
p,p'-TDE	29	7	24.1	0.04	0.01-0.55
Trifluralin	29	2	6.9	<0.01	0.01-0.07
RHODE ISLAND					
Arsenic	1	1	100.0	21.30	21.30
p,p'-DDE	1	1	100.0	0.23	0.23
o,p'-DDT	1	1	100.0	0.25	0.25
p,p'-DDT	1	1	100.0	2.46	2.46
DDTR	1	1	100.0	3.00	3.00
Dieldrin	1	1	100.0	0.11	0.11
p,p'-TDE	1	1	100.0	0.06	0.06
SOUTH CAROLINA					
Aldrin	17	1	5.9	0.01	0.14
Arsenic	17	17	100.0	3.24	0.53-19.54
2,4-D	2	1	50.0	0.02	0.03
o,p'-DDE	17	7	41.2	0.01	0.01-0.05
p,p'-DDE	17	14	82.4	0.24	0.01-0.93
o,p'-DDT	17	12	70.6	0.15	0.01-0.95
p,p'-DDT	17	11	64.7	0.64	0.12-3.15
DDTR	17	15	88.2	1.17	0.01-4.78
Dieldrin	17	3	17.7	0.04	0.02-0.56
Endrin	17	3	17.7	<0.01	0.01-0.05
Heptachlor epoxide	17	3	17.7	<0.01	0.01
Lindane	17	1	5.9	<0.01	0.01
o,p'-TDE	17	5	29.4	0.03	0.03-0.19
p,p'-TDE	17	14	82.4	0.10	0.01-0.34
Toxaphene	17	1	5.9	0.10	1.74
Trifluralin	17	5	29.4	0.01	0.01-0.08
SOUTH DAKOTA					
Arsenic	101	101	100.0	5.80	0.47-34.54
Chlordane	106	3	2.8	0.01	0.10-0.66
p,p'-DDE	106	2	1.9	<0.01	0.01-0.03

TABLE 5.—*Pesticide residues in cropland soil from 43 States—FY 1969*—Continued

COMPOUND	NUMBER OF SAMPLES ANALYZED [1]	NUMBER OF POSITIVE SAMPLES	PERCENT POSITIVE SITES [2]	MEAN RESIDUE LEVEL (PPM)	RANGE OF DETECTED RESIDUES (PPM)
SOUTH DAKOTA—Continued					
o,p'-DDT	106	2	1.9	<0.01	0.01-0.03
p,p'-DDT	106	2	1.9	<0.01	0.02-0.04
DDTR	106	4	3.8	<0.01	0.01-0.10
Dieldrin	106	9	8.5	0.01	0.01-0.25
Heptachlor	106	1	0.9	<0.01	0.01
Heptachlor epoxide	106	3	2.8	<0.01	0.01-0.03
Lindane	106	3	2.8	<0.01	0.01-0.02
p,p'-TDE	106	1	0.9	<0.01	0.02
TENNESSEE					
Arsenic	27	27	100.0	8.05	2.31-15.63
Chlordane	27	1	3.7	0.01	0.20
p,p'-DDE	27	10	37.0	0.02	0.01-0.26
o,p'-DDT	27	7	25.9	0.01	0.01-0.08
p,p'-DDT	27	10	37.0	0.05	0.01-0.38
DDTR	27	11	40.7	0.11	0.01-0.70
Dieldrin	27	6	22.2	<0.01	0.01-0.03
Endrin	27	1	3.7	<0.01	0.02
p,p'-TDE	27	6	22.2	0.03	0.02-0.36
Toxaphene	27	4	14.8	0.14	0.13-2.19
Trifluralin	27	2	7.4	<0.01	0.04-0.05
UTAH					
Arsenic	12	11	91.7	4.16	0.62-12.66
Chlordane	12	4	33.3	0.04	0.02-0.25
p,p'-DDE	12	2	16.7	<0.01	0.01-0.02
p,p'-DDT	12	1	8.3	<0.01	0.03
DDTR	12	2	16.7	0.01	0.01-0.05
Dieldrin	12	2	16.7	0.01	0.02-0.15
Heptachlor	12	2	16.7	0.02	0.02-0.26
Heptachlor epoxide	12	3	25.0	0.01	0.02-0.05
VERMONT					
Arsenic	4	4	100.0	1.79	0.99-2.30
p,p'-DDE	5	1	20.0	<0.01	0.01
DDTR	5	1	20.0	<0.01	0.01
Dieldrin	5	1	20.0	<0.01	0.01
VIRGINIA					
Aldrin	21	1	4.8	<0.01	0.01
Arsenic	20	20	100.0	3.34	0.69-12.34
Chlordane	21	5	23.8	0.01	0.01-0.11
p,p'-DDE	21	11	52.4	0.02	0.01-0.22
o,p'-DDT	21	4	19.1	0.01	0.01-0.17
p,p'-DDT	21	8	38.1	0.11	0.01-1.31
DDTR	21	11	52.4	0.17	0.01-1.75
Dieldrin	21	6	28.6	0.08	0.01-1.60
Heptachlor epoxide	21	4	19.1	0.01	0.01-0.05
Malathion	1	1	100.0	0.04	0.04
Ethyl parathion	1	1	100.0	0.90	0.90
o,p'-TDE	21	1	4.8	<0.01	0.07
p,p'-TDE	21	7	33.3	0.02	0.01-0.19
Toxaphene	21	1	4.7	0.01	0.28

TABLE 3.—*Pesticide residues in cropland soil from 43 States—FY 1969*—Continued

Compound	Number of Samples Analyzed [1]	Number of Positive Samples	Percent Positive Sites [2]	Mean Residue Level (ppm)	Range of Detected Residues (ppm)
WASHINGTON					
Aldrin	45	2	4.4	<0.01	0.09-0.10
Arsenic	45	45	100.0	2.61	0.71-7.02
2,4-D	6	1	16.7	<0.01	0.01
o,p'-DDE	45	2	4.4	<0.01	0.01-0.09
p,p'-DDE	45	10	22.2	0.17	0.01-6.99
o,p'-DDT	45	6	13.3	0.06	0.01-2.58
p,p'-DDT	45	10	22.2	0.46	0.01-19.75
DDTR	45	11	24.4	0.72	0.01-30.69
Dieldrin	45	8	17.8	0.02	0.01-0.30
o,p'-TDE	45	1	2.2	<0.01	0.17
p,p'-TDE	45	3	6.7	0.03	0.01-1.11
Toxaphene	45	1	2.2	0.02	0.73
Trifluralin	45	1	2.2	<0.01	0.08
WEST VIRGINIA					
Arsenic	6	6	100.0	6.33	4.36-8.17
Chlordane	6	3	50.0	0.21	0.09-0.78
p,p'-DDE	6	2	33.3	0.02	0.04-0.10
p,p'-DDT	6	2	33.3	0.01	0.01-0.07
DDTR	6	2	33.3	0.04	0.05-0.17
Dieldrin	6	1	16.7	0.04	0.23
Heptachlor epoxide	6	3	50.0	0.06	0.08-0.18
WISCONSIN					
Aldrin	67	5	7.5	<0.01	0.01-0.04
Arsenic	68	68	100.0	3.78	0.34-10.01
Chlordane	67	3	4.5	0.01	0.04-0.32
o,p'-DDE	67	1	1.5	<0.01	0.02
p,p'-DDE	67	9	13.4	0.01	0.01-0.27
o,p'-DDT	67	3	4.5	0.01	0.05-0.30
p,p'-DDT	67	7	10.5	0.01	0.01-0.30
DDTR	67	9	13.4	0.02	0.01-0.71
Dieldrin	67	9	13.4	0.01	0.01-0.17
Heptachlor	67	2	3.0	<0.01	0.01
Heptachlor epoxide	67	2	3.0	<0.01	0.01
p,p'-TDE	67	4	6.0	<0.01	0.01-0.12
Trifluralin	67	1	1.5	<0.01	0.01
WYOMING					
Arsenic	17	14	82.4	1.71	0.40-10.88
Chlordane	17	4	23.5	0.05	0.03-0.48
Dieldrin	17	6	35.3	0.02	0.02-0.19
Heptachlor epoxide	17	3	17.7	0.01	0.02-0.05

[1] One sample per site.

[2] Percent based on number of sites with residues greater than or equal to the sensitivity limits.

TABLE 4.—*Pesticide residues in noncropland soil from 11 States—FY 1969*

COMPOUND	NUMBER OF SAMPLES ANALYZED [1]	NUMBER OF POSITIVE SAMPLES	PERCENT POSITIVE SITES [2]	MEAN RESIDUE LEVEL (PPM)	RANGE OF DETECTED RESULTS (PPM)
ARIZONA					
Arsenic	44	44	100.0	6.63	1.35-30.64
Chlordane	44	1	2.3	<0.01	0.08
p,p'-DDE	44	8	18.2	<0.01	0.01-0.06
p,p'-DDT	44	1	2.3	<0.01	0.03
DDTR	44	8	18.2	<0.01	0.01-0.09
Dieldrin	44	1	2.3	<0.01	0.03
GEORGIA					
Arsenic	19	18	94.7	1.47	0.53-4.29
p,p'-DDE	10	6	60.0	0.02	0.01-0.07
o,p'-DDT	10	2	20.0	<0.01	0.01-0.02
p,p'-DDT	10	5	50.0	0.02	0.01-0.10
DDTR	10	7	70.0	0.05	0.01-0.12
Dieldrin	10	1	10.0	<0.01	0.01
p,p'-TDE	10	1	10.0	<0.01	0.01
IDAHO					
Arsenic	26	26	100.0	7.73	1.01-39.07
p,p'-DDE	26	3	11.5	<0.01	0.01
o,p'-DDT	26	1	3.9	<0.01	0.02
p,p'-DDT	26	1	3.9	<0.01	0.06
DDTR	26	3	11.5	0.01	0.01-0.11
p,p'-TDE	26	1	3.9	<0.01	0.02
IOWA					
Aldrin	7	1	14.3	<0.01	0.02
Arsenic	7	7	100.0	7.08	1.71-17.39
MAINE					
Arsenic	8	8	100.0	5.14	1.40-13.00
p,p'-DDE	11	1	9.1	0.02	0.16
o,p'-DDT	11	1	9.1	<0.01	0.03
p,p'-DDT	11	1	9.1	0.02	0.23
DDTR	11	1	9.1	0.06	0.62
p,p'-TDE	11	1	9.1	0.02	0.18
MARYLAND					
Arsenic	3	3	100.0	8.43	5.20-11.97
p,p'-DDE	3	1	33.3	0.02	0.05
o,p'-DDT	3	1	33.3	0.01	0.03
p,p'-DDT	3	2	66.7	0.05	0.03-0.11
DDTR	3	2	66.7	0.09	0.03-0.23
p,p'-TDE	3	1	33.3	0.01	0.04
NEBRASKA					
Arsenic	17	16	94.1	2.18	0.33-8.42
Chlordane	19	1	5.3	<0.01	0.04
p,p'-DDE	19	3	15.8	<0.01	0.01-0.04
o,p'-DDT	19	1	5.3	<0.01	0.01
p,p'-DDT	19	1	5.3	<0.01	0.02

TABLE 4.—*Pesticide residues in noncropland soil from 11 States—FY 1969*—Continued

Compound	Number of Samples Analyzed [1]	Number of Positive Samples	Percent Positive Sites [2]	Mean Residue Level (ppm)	Range of Detected Residues (ppm)
NEBRASKA—Continued					
DDTR	19	3	15.8	<0.01	0.01-0.07
Dicofol	19	2	10.5	0.02	0.10-0.29
Dieldrin	19	2	10.5	<0.01	0.01
Heptachlor epoxide	19	1	5.3	<0.01	0.01
VIRGINIA					
Arsenic	10	10	100.0	4.07	0.50-12.42
p,p'-DDT	13	3	23.1	0.01	0.03-0.07
DDTR	13	3	23.1	0.01	0.03-0.09
Dieldrin	13	2	15.4	0.01	0.03-0.09
p,p'-TDE	13	1	7.7	<0.01	0.02
WASHINGTON					
Arsenic	21	21	100.0	6.94	1.58-54.17
p,p'-DDE	21	3	14.3	<0.01	0.01-0.02
p,p'-DDT	21	2	9.5	<0.01	0.01
DDTR	21	3	14.3	<0.01	0.01-0.03
WEST VIRGINIA					
Arsenic	6	6	100.0	5.16	2.67-13.26
p,p'-DDE	8	1	12.5	<0.01	0.02
p,p'-DDT	8	1	12.5	0.01	0.05
DDTR	8	1	12.5	0.01	0.08
Dieldrin	8	1	12.5	0.01	0.04
p,p'-TDE	8	1	12.5	<0.01	0.01
WYOMING					
Arsenic	37	36	97.3	2.73	0.35-19.33
Chlordane	37	1	2.7	0.01	0.50
o,p'-DDE	37	1	2.7	<0.01	0.02
p,p'-DDE	37	1	2.7	0.01	0.31
o,p'-DDT	37	1	2.7	<0.01	0.05
p,p'-DDT	37	1	2.7	<0.01	0.18
DDTR	37	1	2.7	0.02	0.56
Dieldrin	37	1	2.7	<0.01	0.02
Heptachlor epoxide	37	1	2.7	<0.01	0.01
Toxaphene	37	1	2.7	0.01	0.52

[1] One sample per site.

[2] Percent based on number of sites with residues greater than or equal to the sensitivity limits.

TABLE 5.—*Arsenic residue data for the 12 States having the highest residue levels—FY 1969*

State	Number of Samples Analyzed	Percent Positive Sites[1]	Mean Residue Level (ppm)	Range of Detected Residues (ppm)
Arkansas	47	100.0	9.0	1.7-28.2
Kentucky	31	100.0	8.4	2.6-12.8
New England[2]	19	100.0	10.2	1.0-14.1
New York	37	94.6	9.4	1.2-43.9
North Dakota	158	100.0	8.5	1.0-37.5
Ohio	69	100.0	11.2	1.2-41.5
Pennsylvania	29	100.0	10.8	3.0-64.9

[1] Percent based on number of sites with residues greater than or equal to the sensitivity limits.
[2] Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.

TABLE 6.—*Pesticide residue data for 5 States having the highest DDTR residue levels—FY 1969*

State	Number of Samples Analyzed	Percent Positive Sites[1]	Mean Residue Level (ppm)	Range of Detected Residues (ppm)
Alabama	22	90.9	1.13	0.05-8.08
California	65	84.6	1.47	0.01-41.81
Michigan	51	23.5	2.09	0.01-78.36
Mississippi	29	89.7	2.06	0.03-13.14
South Carolina	17	88.2	1.17	0.01-4.78

[1] Percent based on number of sites with residues greater than or equal to the sensitivity limits.

TABLE 7.—*Residue data for the 7 States with the highest dieldrin residue levels—FY 1969*

State	Number of Samples Analyzed	Percent Positive Sites[1]	Mean Residue Level (ppm)	Range of Detected Residues (ppm)
Florida	18	38.9	0.08	0.01-0.52
Illinois	142	61.3	0.11	0.01-1.42
Iowa	151	53.6	0.06	0.01-0.42
Kentucky	31	54.8	0.06	0.01-0.65
North Carolina	31	32.3	0.08	0.01-1.53
Virginia/West Virginia	27	25.9	0.07	0.01-1.60

[1] Percent based on number of sites with residues greater than or equal to the sensitivity limits.

TABLE 8.—*Summary of pesticides used in FY 1969 on cropland for all 43 States*

ALL STATES—1,684 SITES

Compound	Percent of Sites Treated	Average Application Rate (lb/acre)	Average Amount Applied Per Site (lb/acre)
Aldrin	4.16	1.25	0.0522
Amiben	2.14	1.07	0.0229
Aramite	0.12	2.35	0.0028
Atrazine	7.66	1.88	0.1442
Azinphosmethyl	0.59	1.70	0.0101
Azodrin	0.42	2.07	0.0086
Bacillus thuringiensis	0.12	9.50	0.0113
Barban	0.12	0.17	0.0002
Benefin	0.18	1.36	0.0024
Benzene hexachloride	0.06	3.00	0.0018
Bidrin	0.24	0.18	0.0004
Binapacryl	0.06	2.12	0.0013
Bordeaux mixtures	0.06	0.50	0.0003
Cacodylic acid	0.06	0.01	0.0000
Captan	11.16	0.12	0.0133
Carbaryl	1.72	3.64	0.0627
Carbophenothion	0.18	1.83	0.0033
CDAA	0.89	1.78	0.0158
Ceresan L	1.25	0.01	0.0002
Ceresan M	1.48	0.01	0.0001
Ceresan red	1.84	0.01	0.0003
Chevron RE-5353	0.30	1.72	0.0051
Chlordane	0.12	3.10	0.0037
Chlorobenzilate	0.12	1.31	0.0016
Chloroneb	0.36	0.05	0.0002
Chloroxuron	0.30	1.65	0.0049
Chromophon	0.06	0.15	0.0001
CIPC	0.12	1.50	0.0018
Copper carbonate	0.06	0.60	0.0004
Copper oxide	0.18	4.23	0.0075
Copper oxychloride sulfate	0.12	4.68	0.0056
Copper-8-quinolinolate	0.06	0.01	0.0000
Copper sulfate	0.36	13.53	0.0482
Cotoran	0.48	0.74	0.0035
2,4-D	15.14	0.54	0.0825
2,4-DB	0.89	0.48	0.0042
Dalapon	0.42	2.12	0.0088
DDT technical	3.44	5.56	0.1915
DEF	0.59	1.66	0.0099
Demeton	0.18	0.59	0.0011
Diazinon	1.96	1.22	0.0240
Dicamba	0.30	0.39	0.0012
Dichlone	0.12	2.00	0.0024
Dichloropropane	0.06	54.43	0.0323
Dichloropropene	0.36	70.07	0.2496
Dichlorprop	0.06	2.00	0.0012
Dicofol	0.42	2.12	0.0088
Dieldrin	1.19	0.17	0.0021
Difolatan	0.06	0.01	0.0000
Dimetan	0.06	0.01	0.0000
Dimethoate	0.12	0.75	0.0009
Dinitrobutylphenol	0.95	3.78	0.0359
Dinitrocresol	0.06	3.00	0.0018
Dinocap	0.12	0.22	0.0003
Dioxathion	0.12	2.60	0.0031
Diphenamid	0.24	2.19	0.0052
Diquat	0.06	0.83	0.0005
Disulfoton	1.72	1.77	0.0305
Dithane M-45	0.30	5.82	0.0173
Diuron	1.13	0.93	0.0105
DSMA	0.36	1.52	0.0054
Endosulfan (1)	0.48	1.11	0.0053
Endrin	0.48	2.21	0.0105
EPN	0.06	1.50	0.0009
EPTC	0.36	2.65	0.0094
Ethion	0.24	2.06	0.0049
Ethylene dibromide	0.12	14.62	0.0174
Falone	0.06	2.00	0.0012
Ferbam	0.06	9.12	0.0054
Folex	0.06	1.50	0.0009
Heptachlor	1.96	0.33	0.0065
Herbisan	0.06	10.00	0.0060
Hexachlorobenzene	0.06	0.01	0.0000
Lead arsenate	0.06	3.80	0.0023
Lindane	0.65	0.03	0.0002
Linuron	0.77	0.73	0.0056
Malathion	7.54	0.17	0.0127
Maleic hydrazide	0.36	1.43	0.0051
Maneb	0.30	2.14	0.0064
MCPA	1.07	0.33	0.0035
Methoxychlor	2.20	0.04	0.0008
Methyl demeton	0.06	1.50	0.0009
Methylmercury dicyandiamide	5.46	0.01	0.0006
Methylmercury nitrile	0.06	0.01	0.0000
Mevinphos	0.36	1.48	0.0053
Mirex	0.24	0.01	0.0000
Monuron	0.06	1.60	0.0010
MSMA	0.48	1.21	0.0058
Nabam	0.24	1.78	0.0042
Naled	0.30	1.62	0.0048
Nitralin	0.36	0.76	0.0027
Nitrate	1.13	64.58	0.7286
Norea	0.12	0.46	0.0006
NPA	0.36	1.01	0.0036
Oxydemetonmethyl	0.18	0.40	0.0007
Ethyl parathion	1.84	1.48	0.0272
Methyl parathion	3.03	3.07	0.0929
PCNB	0.42	1.59	0.0066
PCP	0.06	1.50	0.0009
Phenylmercury urea	0.06	0.01	0.0000
Phorate	0.65	2.17	0.0142
Phosphamidon	0.12	0.13	0.0002
Picloram	0.12	0.63	0.0007
PMA	0.18	0.06	0.0001
Polyram	0.06	10.40	0.0062
Prometryne	0.06	2.00	0.0012
Propanil	0.42	3.96	0.0165
Propazine	0.06	2.00	0.0012
Ramrod	1.37	1.45	0.0198
Ro-Neet	0.12	1.88	0.0022
Roundup	0.12	0.78	0.0009
Randox T	0.12	0.90	0.0011
Silvex	0.12	0.63	0.0007
Simazine	0.12	2.07	0.0025
Simetryne	0.06	2.00	0.0012
Sodium arsenite	0.24	5.25	0.0125
Sodium chlorate	0.06	6.00	0.0036

TABLE 8.—*Summary of pesticides used in FY 1969 on cropland for all 43 States*—Continued

Compound	Percent of Sites Treated	Average Application Rate (lb/acre)	Average Amount Applied Per Site (lb/acre)
Strobane	0.12	16.50	0.0196
Sulfur	0.71	34.00	0.2423
2,4,5-T	0.18	0.83	0.0015
TCA	0.06	2.00	0.0012
TDE technical	0.36	2.31	0.0082
Tetradifon	0.12	0.50	0.0006
Thiram	1.07	0.03	0.0003
Toxaphene	1.90	9.87	0.1876
Trichlorofon	0.06	0.80	0.0005
Trifluralin	4.33	0.76	0.0327
Vernolate	0.53	1.29	0.0069
Zineb	0.18	4.90	0.0087
Ziram	0.06	0.80	0.0005

TABLE 9.—*Summary of pesticides used in FY 1969 on noncropland for all 11 States*

ALL STATES—195 SITES

Compound	Percent of Sites Treated	Average Application Rate (lb/acre)	Average Amount Applied Per Site (lb/acre)
2,4-D	0.51	2.00	0.0103
Malathion	0.51	0.61	0.0031
Mirex	0.51	0.01	0.0001

TABLE 10.—*Summary of pesticides used in FY 1969 on cropland by State*

Compound	Percent of Sites Treated	Average Application Rate (lb/acre)	Average Amount Applied Per Site (lb/acre)
ALABAMA—23 SITES			
Azodrin	4.35	0.84	0.0365
Benzene hexachloride	4.35	3.00	0.1304
Captan	21.74	0.04	0.0083
Carbaryl	4.35	0.40	0.0174
Ceresan M	4.35	0.01	0.0004
Copper sulfate	8.70	36.08	3.1374
Cotoran	4.35	1.50	0.0652
DDT technical	39.13	10.73	4.2000
DEF	4.35	1.50	0.0652
Disulfoton	8.70	0.35	0.0304
Diuron	8.70	0.95	0.0826
DSMA	4.35	1.00	0.0435
Endrin	8.70	1.20	0.1043
EPN	4.35	1.50	0.0652
ALABAMA—23 SITES—Continued			
Malathion	8.70	2.50	0.2174
Ethyl parathion	4.35	1.00	0.0435
Methyl parathion	52.17	3.42	1.7848
MSMA	8.70	1.50	0.1304
Phorate	4.35	1.00	0.0435
Prometryne	4.35	2.00	0.0870
Thiram	4.35	0.02	0.0009
Toxaphene	17.39	3.45	0.6000
Trifluralin	47.83	0.61	0.2913
Vernolate	8.70	1.05	0.0913
ARIZONA—9 SITES			
Azodrin	11.11	6.25	0.6944
Captan	11.11	0.01	0.0011
Ceresan L	11.11	0.01	0.0011
Demeton	11.11	0.13	0.0144
Dieldrin	11.11	0.01	0.0011
Diuron	11.11	1.00	0.1111
Endosulfan (1)	11.11	2.00	0.2222
Naled	11.11	0.50	0.0556
Ethyl parathion	22.22	5.50	1.2222
Methyl parathion	44.44	2.75	1.2244
PCNB	11.11	0.75	0.0833
Phorate	11.11	1.50	0.1667
Strobane	11.11	15.00	1.6667
Toxaphene	11.11	2.00	0.2222
Trifluralin	22.22	1.12	0.2500
ARKANSAS—45 SITES			
Aldrin	2.22	0.25	0.0056
Captan	13.33	0.03	0.0036
Ceresan M	2.22	0.01	0.0002
Chloroxuron	6.67	1.00	0.0667
2,4-D	2.22	0.05	0.0011
2,4-DB	2.22	1.75	0.0369
DEF	2.22	1.00	0.0222
Dinitrobutylphenol	6.67	1.58	0.1056
Disulfoton	2.22	0.01	0.0002
Diuron	2.22	0.75	0.0167
DSMA	4.44	3.00	0.1333
Endrin	2.22	12.00	0.2667
Linuron	8.89	0.94	0.0833
NPA	6.67	0.54	0.0362
Nitralin	2.22	0.44	0.0098
Methyl parathion	2.22	12.00	0.2667
Propanil	4.44	5.50	0.2444
2,4,5-T	4.44	0.88	0.0359
Thiram	4.44	0.03	0.0016
Trifluralin	15.56	0.79	0.1222
CALIFORNIA—66 SITES			
Aramite	3.03	2.35	0.0712
Atrazine	1.52	2.50	0.0379

TABLE 10.—*Summary of pesticides used in FY 1969 on cropland by State*—Continued

Compound	Percent of Sites Treated	Average Application Rate (lb/acre)	Average Amount Applied Per Site (lb/acre)
CALIFORNIA—66 SITES—Continued			
Azinphosmethyl	3.03	0.48	0.0145
Bacillus thuringiensis	3.03	9.50	0.2879
Benefin	1.52	1.83	0.0277
Binapacryl	1.52	2.12	0.0321
Bordeaux mixtures	1.52	0.50	0.0076
Captan	1.52	2.30	0.0348
Carbaryl	6.06	10.76	0.6521
Carbophenothion	3.03	1.75	0.0530
Ceresan red	3.03	0.01	0.0003
Chlordane	1.52	5.00	0.0758
2,4-D	3.03	0.63	0.0189
DDT technical	13.64	2.82	0.3844
Diazinon	6.06	0.99	0.0603
Dichloropropene	4.55	8.67	0.3939
Dichlorprop	1.52	2.00	0.0303
Dicofol	7.58	2.59	0.1962
Dimethoate	1.52	1.00	0.0152
Dioxathion	3.03	2.60	0.0788
Diphenamid	1.52	2.62	0.0397
Disulfoton	3.03	4.00	0.1212
Diuron	1.52	0.75	0.0114
Dithane M-45	3.03	5.00	0.1515
Endosulfan (1)	7.58	0.99	0.0750
Ethion	3.03	1.38	0.0417
Malathion	4.55	1.65	0.0750
MCPA	3.03	0.76	0.0230
Mevinphos	9.09	1.48	0.1345
Nabam	1.52	3.50	0.0530
Naled	6.06	1.90	0.1152
Ethyl parathion	6.06	2.03	0.1230
Methyl parathion	4.55	6.10	0.2773
Propanil	3.03	3.63	0.1098
Simazine	1.52	3.75	0.0568
Simetryne	1.52	2.00	0.0303
Sulfur	7.58	35.79	2.7115
Tetradifon	3.03	0.50	0.0152
Toxaphene	6.06	9.75	0.5908
Trichlorofon	1.52	0.80	0.0121
Trifluralin	6.06	0.88	0.0530
COLORADO—60 SITES			
Aldrin	3.33	0.08	0.0027
Carbaryl	1.67	1.00	0.0167
Ceresan M	1.67	0.01	0.0002
2,4-D	10.00	0.51	0.0508
2,4-DB	1.67	0.70	0.0117
Endrin	5.00	0.33	0.0167
Malathion	1.67	0.60	0.0100
Ethyl parathion	1.67	0.25	0.0042
Picloram	1.67	1.00	0.0167
PMA	1.67	0.15	0.0025
CONNECTICUT—2 SITES			
Atrazine	50.00	2.50	1.2500

Compound	Percent of Sites Treated	Average Application Rate (lb/acre)	Average Amount Applied Per Site (lb/acre)
DELAWARE—3 SITES			
Captan	33.33	0.04	0.0133
Lindane	33.33	0.08	0.0267
FLORIDA—15 SITES			
Atrazine	6.67	0.80	0.0533
Azinphosmethyl	6.67	2.50	0.1667
Captan	6.67	7.50	0.5000
Carbophenothion	6.67	2.00	0.1333
Chlorobenzilate	13.33	1.31	0.1753
Copper oxide	6.67	7.50	0.5000
Copper oxychloride sulfate	6.67	8.00	0.5333
2,4-D	6.67	1.50	0.1000
Dalapon	6.67	1.70	0.1133
DDT technical	6.67	7.00	0.4667
Diazinon	6.67	2.90	0.1933
Dichloropropene	6.67	194.40	12.9500
Dicofol	6.67	1.50	0.1000
Ethion	13.33	2.75	0.3667
Ferbam	6.67	9.12	0.6080
Mirex	6.67	0.01	0.0007
Ethyl parathion	13.33	2.85	0.3800
Methyl parathion	6.67	10.00	0.6667
Sulfur	6.67	46.50	3.1000
2,4,5-T	6.67	0.75	0.0500
TDE technical	6.67	10.00	0.6667
Toxaphene	6.67	2.00	0.1333
Zineb	13.33	6.55	0.8733
GEORGIA—28 SITES			
Atrazine	7.14	3.00	0.2143
Azodrin	3.57	4.00	0.1429
Benefin	7.14	1.12	0.0800
Captan	39.29	0.08	0.0307
Ceresan red	10.71	0.01	0.0011
Copper oxychloride sulfate	3.57	1.36	0.0486
Copper sulfate	3.57	2.72	0.0971
2,4-D	10.71	0.50	0.0536
DDT technical	21.43	14.18	3.0395
Disulfoton	3.57	2.00	0.0714
Folex	3.57	1.50	0.0536
Malathion	21.43	0.34	0.0732
Maleic hydrazide	7.14	2.41	0.1725
Methoxychlor	28.57	0.02	0.0046
Mirex	3.57	0.01	0.0004
Ethyl parathion	3.57	1.00	0.0357
Methyl parathion	14.29	1.84	0.2632
PCNB	3.57	10.00	0.3571
Sulfur	7.14	40.20	2.8714
Thiram	10.71	0.04	0.0043
Toxaphene	17.86	14.45	2.5504
Trifluralin	7.14	1.25	0.0893

TABLE 10.—*Summary of pesticides used in FY 1969 on cropland by State*—Continued

COMPOUND	PERCENT OF SITES TREATED	AVERAGE APPLICATION RATE (LB/ACRE)	AVERAGE AMOUNT APPLIED PER SITE (LB/ACRE)
IDAHO—33 SITES			
Captan	12.12	0.01	0.0015
Ceresan M	6.06	0.01	0.0006
Ceresan L	15.15	0.01	0.0015
CIPC	3.03	2.00	0.0606
2,4-D	12.12	2.12	0.2576
2,4-DB	3.03	0.50	0.0152
DDT technical	6.06	0.50	0.0303
Dieldrin	3.03	0.01	0.0003
Diquat	3.03	0.83	0.0252
EPTC	3.03	0.38	0.0115
Hexachlorobenzene	3.03	0.01	0.0003
Ro-Neet	6.06	1.87	0.1136
Trifluralin	6.06	0.56	0.0342
ILLINOIS—141 SITES			
Aldrin	19.15	1.52	0.2914
Amiben	7.80	0.91	0.0707
Atrazine	9.22	2.19	0.2023
Captan	49.65	0.06	0.0317
Carbaryl	0.71	4.80	0.0340
CDAA	7.80	1.51	0.1176
Ceresan red	0.71	0.01	0.0001
Ceresan L	0.71	0.06	0.0004
Chevron RE-5353	1.42	2.56	0.0363
2,4-D	20.57	0.42	0.0864
2,4-DB	2.13	0.35	0.0075
Diazinon	3.55	1.86	0.0659
Dieldrin	2.13	0.23	0.0050
Heptachlor	9.93	0.46	0.0455
Linuron	1.42	0.66	0.0094
Malathion	39.72	0.03	0.0104
Methoxychlor	10.64	0.01	0.0011
Ramrod	7.80	1.22	0.0955
Roundup	0.71	0.07	0.0005
Silvex	0.71	0.25	0.0018
Thiram	0.71	0.01	0.0001
Trifluralin	2.84	0.97	0.0277
Vernolate	0.71	0.37	0.0026
INDIANA—75 SITES			
Aldrin	10.67	1.11	0.1187
Amiben	5.33	0.85	0.0453
Atrazine	13.33	1.79	0.2393
Captan	26.67	0.01	0.0027
Carbaryl	1.33	1.60	0.0213
CDAA	1.33	1.07	0.0143
Ceresan L	2.67	0.01	0.0003
2,4-D	10.67	0.35	0.0373
DDT technical	1.33	0.01	0.0001
Dieldrin	1.33	0.01	0.0001
Difolatan	1.33	0.01	0.0001
Heptachlor	5.33	0.32	0.0172
Malathion	17.33	0.01	0.0017
Methoxychlor	4.00	0.01	0.0004
INDIANA—75 SITES—Continued			
Methylmercury dicyandiamide	2.67	0.01	0.0003
Ramrod	2.67	1.40	0.0373
Roundup	1.33	1.50	0.0200
Trifluralin	2.67	0.75	0.0200
Zineb	1.33	1.60	0.0213
IOWA—151 SITES			
Aldrin	8.61	0.68	0.0587
Amiben	8.61	1.12	0.0966
Atrazine	10.60	2.00	0.2123
Captan	2.65	0.03	0.0008
Carbaryl	0.66	1.00	0.0066
CDAA	1.32	1.50	0.0199
Chevron RE-5353	0.66	1.00	0.0065
2,4-D	20.53	0.62	0.1278
Diazinon	6.62	1.19	0.0791
Dicamba	0.66	0.50	0.0033
Dieldrin	0.66	0.15	0.0010
Heptachlor	4.64	0.35	0.0164
Lindane	1.32	0.06	0.0009
Ethyl parathion	0.66	0.32	0.0021
Phorate	1.32	0.95	0.0126
Ramrod	3.97	2.02	0.0801
Randox T	0.66	0.40	0.0026
Thiram	0.66	0.06	0.0004
Trifluralin	2.65	0.47	0.0125
KENTUCKY—31 SITES			
Aldrin	9.68	2.00	0.1935
Atrazine	19.35	1.33	0.2581
2,4-D	3.23	0.50	0.0161
Dalapon	3.23	1.50	0.0484
DDT technical	3.23	3.00	0.0968
EPTC	3.23	1.50	0.0484
LOUISIANA—27 SITES			
Aldrin	22.22	0.08	0.0178
Captan	3.70	0.25	0.0093
Carbaryl	3.70	12.00	0.4444
Ceresan L	3.70	0.01	0.0004
Cotoran	3.70	1.00	0.0370
2,4-D	11.11	1.58	0.1759
Dalapon	3.70	2.00	0.0741
DDT technical	7.41	23.25	1.7222
DEF	3.70	9.00	0.3333
Dimetan	3.70	0.01	0.0004
Malathion	3.70	1.00	0.0370
Methylmercury dicyandiamide	3.70	0.01	0.0004
Methylmercury nitrile	3.70	0.01	0.0004
MSMA	3.70	1.50	0.0556
Nitrate	22.22	72.00	16.0000

TABLE 10.—*Summary of pesticides used in FY 1969 on cropland by State*—Continued

Compound	Percent of Sites Treated	Average Application Rate (lb/acre)	Average Amount Applied Per Site (lb/acre)
LOUISIANA—27 SITES—Continued			
Methyl parathion	7.41	7.20	0.5333
Propanil	11.11	3.17	0.3519
Silvex	3.70	1.00	0.0370
Strobane	3.70	18.00	0.6667
TCA	3.70	2.00	0.0741
Toxaphene	3.70	75.00	2.7778
Trifluralin	3.70	1.00	0.0370
MAINE—8 SITES			
Dalapon	12.50	4.90	0.6125
Dinitrobutylphenol	37.50	1.37	0.5125
Disulfoton	25.00	8.50	2.1250
Malathion	12.50	1.00	0.1250
Maneb	12.50	0.70	0.0875
Sodium arsenite	25.00	8.80	2.2000
MARYLAND—13 SITES			
Atrazine	30.77	1.26	0.3885
Captan	30.77	0.03	0.0100
2,4-D	15.38	0.54	0.0838
Dieldrin	7.69	0.01	0.0008
Lindane	15.38	0.01	0.0015
Malathion	23.08	0.01	0.0023
Methoxychlor	7.69	0.01	0.0008
Thiram	7.69	0.01	0.0008
MASSACHUSETTS—2 SITES			
Carbaryl	50.00	0.83	0.4150
Dinitrobutylphenol	50.00	3.06	1.5300
Disulfoton	50.00	1.50	0.7500
Dithane M-45	50.00	12.40	6.2000
Maleic hydrazide	50.00	2.32	1.1600
Oxydemetonmethyl	50.00	0.25	0.1250
Ethyl parathion	50.00	0.53	0.2650
MICHIGAN—51 SITES			
Atrazine	11.76	1.49	0.1753
Azinphosmethyl	1.96	8.00	0.1569
Captan	1.96	0.01	0.0002
CDAA	1.96	6.00	0.1176
Ceresan red	1.96	0.01	0.0002
CIPC	1.96	1.00	0.0196
Chloroxuron	3.92	2.63	0.1029
2,4-D	9.80	0.53	0.0524
DDT technical	1.96	1.50	0.0294
Dinitrobutylphenol	1.96	11.25	0.2206
Diuron	1.96	2.00	0.0392
EPTC	1.96	2.00	0.0392
Herbisan	1.96	10.00	0.1961
Malathion	3.92	0.50	0.0198
Methoxychlor	1.96	0.01	0.0002
MISSISSIPPI—29 SITES			
Azinphosmethyl	3.45	0.25	0.0066
Azodrin	6.90	0.76	0.0524
Bidrin	6.90	0.03	0.0024
Captan	24.14	0.09	0.0210
Ceresan M	3.45	0.01	0.0003
Ceresan red	27.59	0.02	0.0045
Ceresan L	3.45	0.01	0.0003
Chloroneb	17.24	0.06	0.0100
Cotoran	13.79	0.47	0.0652
DDT technical	31.03	3.47	1.0759
DEF	20.69	0.82	0.1690
Disulfoton	31.03	0.05	0.0152
Diuron	17.24	0.63	0.1079
DSMA	10.34	0.70	0.0728
Endrin	3.45	2.00	0.0690
Linuron	3.45	0.42	0.0145
Malathion	6.90	1.40	0.0969
Methoxychlor	3.45	0.01	0.0003
Mirex	6.90	0.01	0.0007
MSMA	10.34	1.44	0.1486
Norea	3.45	0.33	0.0114
Nitralin	13.79	0.99	0.1372
Methyl parathion	41.38	2.14	0.8841
PCNB	10.34	0.13	0.0131
Sodium chlorate	3.45	6.00	0.2069
Toxaphene	34.48	7.50	2.5862
Trifluralin	37.93	0.85	0.3241
Vernolate	3.45	0.30	0.0103
MISSOURI—81 SITES			
Aldrin	4.94	1.65	0.0815
Amiben	4.94	1.15	0.0568
Atrazine	12.35	1.87	0.2315
Bidrin	1.23	0.10	0.0012
Captan	1.23	0.01	0.0001
Ceresan M	1.23	0.01	0.0001
2,4-D	11.11	0.77	0.0856
2,4-DB	2.47	0.25	0.0062
Diazinon	1.23	0.93	0.0115
Dinitrobutylphenol	2.47	0.53	0.0131
Heptachlor	1.23	0.19	0.0023
Linuron	2.47	0.37	0.0091
NPA	2.47	1.07	0.0264
Methyl parathion	1.23	0.50	0.0062
Propazine	1.23	2.00	0.0247
Ramrod	1.23	1.10	0.0136
Trifluralin	7.41	0.91	0.0673
Vernolate	2.47	1.38	0.0340
NEBRASKA—103 SITES			
Amiben	0.97	2.50	0.0243
Atrazine	4.85	0.82	0.0400
Captan	17.48	0.04	0.0069
Ceresan red	0.97	0.01	0.0001

TABLE 10.—*Summary of pesticides used in FY 1969 on cropland by State*—Continued

Compound	Percent of Sites Treated	Average Application Rate (lb/acre)	Average Amount Applied Per Site (lb/acre)
NEBRASKA—103 SITES—Continued			
Ceresan L	0.97	0.01	0.0001
Chevron RE-5353	1.94	1.25	0.0243
2,4-D	14.56	0.44	0.0644
Diazinon	4.85	0.98	0.0476
Dieldrin	3.88	0.01	0.0004
Disulfoton	0.97	0.22	0.0021
EPTC	0.97	3.00	0.0291
Malathion	17.48	0.01	0.0017
Methoxychlor	1.94	0.01	0.0002
Methylmercury dicyandiamide	4.85	0.01	0.0005
Nabam	0.97	0.01	0.0001
Norea	0.97	0.60	0.0058
Ethyl parathion	3.88	0.50	0.0194
Phorate	0.97	0.90	0.0087
Ramrod	0.97	0.83	0.0081
Thiram	4.85	0.03	0.0014
NEW JERSEY—5 SITES			
2,4-D	40.00	0.31	0.1240
Monuron	20.00	1.60	0.3200
Ethyl parathion	20.00	0.54	0.1080
Sulfur	20.00	9.00	1.8000
NEW MEXICO—10 SITES			
Azodrin	10.00	1.50	0.1500
Carbaryl	10.00	2.50	0.2500
DDT technical	10.00	1.00	0.1000
Diuron	20.00	1.12	0.2250
Ethyl parathion	10.00	2.50	0.2500
Toxaphene	10.00	1.00	0.1000
NEW YORK—38 SITES			
Atrazine	23.68	1.36	0.3211
Azinphosmethyl	5.26	1.15	0.0605
Captan	13.16	0.87	0.1150
Carbaryl	5.26	1.55	0.0816
Copper sulfate	2.63	3.00	0.0789
2,4-D	7.89	0.21	0.0166
Dalapon	2.63	2.50	0.0658
DDT technical	5.26	1.35	0.0711
Demeton	2.63	0.04	0.0011
Diazinon	2.63	1.00	0.0263
Dichlone	2.63	2.20	0.0579
Dinitrobutylphenol	5.26	15.22	0.8013
Diuron	5.26	2.40	0.1263
Endosulfan (1)	5.26	0.95	0.0500
Lead arsenate	2.63	3.80	0.1000
Malathion	5.26	0.01	0.0005
MCPA	5.26	0.33	0.0176
Methoxychlor	2.63	0.01	0.0003
Methylmercury dicyandiamide	10.53	0.01	0.0011
NEW YORK—38 SITES—Continued			
Nabam	2.63	2.40	0.0632
Nitrate	7.89	26.17	2.0658
Oxydemetonmethyl	2.63	0.15	0.0039
Ethyl parathion	5.26	0.45	0.0239
Phosphamidon	2.63	0.15	0.0039
Sodium arsenite	2.63	0.90	0.0237
NORTH CAROLINA—29 SITES			
Aldrin	6.90	1.75	0.1207
Atrazine	6.90	2.75	0.1897
Carbaryl	20.69	1.43	0.2966
Ceresan red	3.45	0.10	0.0034
Chromophon	3.45	0.15	0.0052
Copper carbonate	3.45	0.60	0.0207
Copper-8-quinolinolate	3.45	0.01	0.0003
2,4-D	20.69	1.00	0.2079
2,4-DB	3.45	0.07	0.0024
DDT technical	13.79	0.70	0.0962
Diazinon	13.79	1.12	0.1545
Dicamba	3.45	1.20	0.0414
Dichloropropene	3.45	20.00	0.6897
Dieldrin	6.90	1.25	0.0866
Dinitrobutylphenol	3.45	1.50	0.0517
Diphenamid	6.90	1.07	0.0741
EPTC	3.45	4.00	0.1379
Ethylene dibromide	3.45	6.00	0.2069
Lindane	3.45	0.01	0.0003
Maleic hydrazide	10.34	0.47	0.0486
Ethyl parathion	6.90	0.50	0.0345
Methyl parathion	3.45	0.83	0.0286
Phorate	6.90	1.13	0.0783
Sulfur	3.45	11.10	0.3828
TDE technical	10.34	0.26	0.0272
Thiram	6.90	0.01	0.0007
Toxaphene	6.90	8.65	0.5966
Trifluralin	3.45	0.57	0.0197
Vernolate	6.90	1.85	0.1276
NORTH DAKOTA—159 SITES			
Barban	1.26	0.17	0.0021
Captan	0.63	0.01	0.0001
Ceresan M	0.63	0.01	0.0001
Ceresan red	2.52	0.01	0.0003
Ceresan L	5.03	0.01	0.0005
2,4-D	42.14	0.40	0.1673
Dicamba	1.89	0.08	0.0016
Disulfoton	0.63	3.00	0.0189
Endrin	0.63	0.25	0.0016
Heptachlor	1.26	0.04	0.0005
Lindane	1.89	0.02	0.0004
Malathion	0.63	0.01	0.0001
Maneb	0.63	1.50	0.0094
MCPA	5.66	0.30	0.0171
Methylmercury dicyandiamide	41.51	0.01	0.0042

TABLE 10.—*Summary of pesticides used in FY 1969 on cropland by State*—Continued

Compound	Percent of Sites Treated	Average Application Rate (lb/acre)	Average Amount Applied Per Site (lb/acre)
NORTH DAKOTA—159 SITES—Continued			
Phenylmercury urea	0.63	0.01	0.0001
PMA	1.26	0.01	0.0001
Polyram	0.63	10.40	0.0654
OHIO—66 SITES			
Aldrin	6.06	3.00	0.1818
Amiben	3.03	1.75	0.0530
Atrazine	12.12	1.20	0.1455
Captan	12.12	0.02	0.0021
Ceresan M	1.52	0.01	0.0002
Copper sulfate	1.52	1.60	0.0242
2,4-D	19.70	0.44	0.0859
Dalapon	1.52	1.50	0.0227
Diazinon	1.52	0.50	0.0076
Dichlone	1.52	1.80	0.0273
Dieldrin	1.52	0.01	0.0002
Dinocap	1.52	0.01	0.0002
Dithane M-45	1.52	0.30	0.0045
Linuron	1.52	0.75	0.0114
Malathion	10.61	0.01	0.0011
Maneb	3.03	0.75	0.0227
Methylmercury dicyandiamide	1.52	0.05	0.0008
NPA	1.52	2.27	0.0344
PCP	1.52	1.50	0.0227
Picloram	1.52	0.25	0.0038
Randox T	1.52	1.40	0.0212
Sulfur	1.52	25.00	0.3788
TDE technical	1.52	0.80	0.0121
Trifluralin	1.52	1.00	0.0152
Ziram	1.52	0.80	0.0121
OKLAHOMA—65 SITES			
Cacodylic acid	1.54	0.01	0.0002
Captan	4.62	0.01	0.0005
Carbaryl	1.54	0.30	0.0046
Ceresan M	20.00	0.01	0.0020
Ceresan red	12.31	0.01	0.0012
Chloroneb	1.54	0.01	0.0002
2,4-D	6.15	0.86	0.0531
2,4-DB	4.62	0.50	0.0231
Dieldrin	4.62	0.01	0.0005
Dimethoate	1.54	0.50	0.0077
Dinitrobutylphenol	1.54	2.00	0.0308
Disulfoton	7.69	0.58	0.0445
Falone	1.54	2.00	0.0308
Methylmercury dicyandiamide	1.54	0.01	0.0002
Nitrate	10.77	16.64	1.7923
Ethyl parathion	3.08	0.75	0.0231
Methyl parathion	12.31	0.65	0.0800
PCNB	1.54	0.01	0.0002
Phosphamidon	1.54	0.12	0.0018
Thiram	1.54	0.01	0.0002
Trifluralin	4.62	1.10	0.0508
PENNSYLVANIA—31 SITES			
Atrazine	19.35	1.57	0.3032
Azinphosmethyl	3.23	0.50	0.0161
Captan	3.23	0.01	0.0003
Carbaryl	3.23	0.32	0.0103
Chlordane	3.23	1.20	0.0387
Copper sulfate	3.23	1.70	0.0548
2,4-D	16.13	0.92	0.1454
DDT technical	9.68	0.83	0.0806
Dicofol	3.23	0.42	0.0135
Dinitrobutylphenol	3.23	0.82	0.0265
Dinitrocresol	3.23	3.00	0.0968
Dinocap	3.23	0.44	0.0142
Diuron	3.23	0.32	0.0103
Lindane	3.23	0.02	0.0006
Linuron	3.23	1.00	0.0323
Maneb	3.23	7.00	0.2258
Methyl demeton	3.23	1.50	0.0484
Nitrate	3.23	100.00	3.2258
Ethyl parathion	6.45	0.45	0.0290
Phorate	3.23	12.50	0.4032
Simazine	3.23	0.40	0.0129
Sodium arsenite	3.23	2.50	0.0806
Trifluralin	3.23	0.75	0.0242
RHODE ISLAND—1 SITE			
Carbaryl	100.00	0.80	0.8000
DDT technical	100.00	2.00	2.0000
Disulfoton	100.00	2.00	2.0000
Dithane M-45	100.00	6.40	6.4000
EPTC	100.00	5.00	5.0000
Oxydemetonmethyl	100.00	0.80	0.8000
SOUTH CAROLINA—17 SITES			
Azodrin	5.88	0.40	0.0235
Carbaryl	17.65	7.19	1.2682
2,4-D	11.76	0.40	0.0471
DDT technical	29.41	2.46	0.7229
DEF	5.88	0.20	0.0118
Demeton	5.88	1.60	0.0941
Diuron	5.88	0.72	0.0424
MSMA	5.88	0.45	0.0265
Nabam	5.88	1.20	0.0706
Ethyl parathion	11.76	0.51	0.0600
Methyl parathion	11.76	5.10	0.6000
Phorate	5.88	0.20	0.0118
TDE technical	5.88	2.25	0.1324
Toxaphene	17.65	6.17	1.0894
Trifluralin	35.29	0.21	0.0753
SOUTH DAKOTA—106 SITES			
Atrazine	1.89	1.40	0.0264
Captan	10.38	0.01	0.0010
Carbaryl	0.94	1.05	0.0099

TABLE 10.—*Summary of pesticides used in FY 1969 on cropland by State*—Continued

Compound	Percent of Sites Treated	Average Application Rate (lb/acre)	Average Amount Applied Per Site (lb/acre)
SOUTH DAKOTA—106 SITES—Continued			
Ceresan M	0.94	0.01	0.0001
2,4-D	26.42	0.47	0.1230
Dalapon	0.94	0.74	0.0070
Dieldrin	1.89	0.01	0.0002
Heptachlor	3.77	0.02	0.0007
Lindane	0.94	0.01	0.0001
Malathion	6.60	0.01	0.0007
MCPA	4.72	0.20	0.0095
Methoxychlor	3.77	0.01	0.0004
Methylmercury dicyandiamide	10.38	0.01	0.0010
Phorate	0.94	0.60	0.0057
Ramrod	0.94	1.00	0.0094
Thiram	0.94	0.01	0.0001
TENNESSEE—28 SITES			
Atrazine	21.43	1.98	0.4250
Bidrin	3.57	0.54	0.0193
Captan	10.71	0.01	0.0011
Ceresan M	7.14	0.01	0.0007
Ceresan red	3.57	0.01	0.0004
Cotoran	7.14	0.78	0.0557
2,4-DB	7.14	0.43	0.0307
Disulfoton	3.57	0.01	0.0004
Diuron	7.14	0.06	0.0046
Linuron	7.14	0.75	0.0536
Malathion	3.57	0.01	0.0004
Methylmercury dicyandiamide	3.57	0.01	0.0004
MSMA	3.57	0.46	0.0164
Nitrate	7.14	250.00	17.8571
Nitralin	3.57	0.15	0.0054
PCNB	3.57	0.01	0.0004
Trifluralin	14.29	0.38	0.0543
UTAH—12 SITES			
Dichloropropene	8.33	180.00	15.0000
Heptachlor	8.33	0.34	0.0283
VIRGINIA—20 SITES			
Atrazine	5.00	4.00	0.2000
Azinphosmethyl	5.00	2.00	0.1000
Carbaryl	5.00	2.75	0.1375
Copper oxide	10.00	2.60	0.2600
2,4-D	10.00	1.12	0.1125
2,4-DB	5.00	0.20	0.0100
DDT technical	5.00	2.00	0.1000
Diazinon	5.00	0.50	0.0250
Dinitrobutylphenol	5.00	1.50	0.0750
Diphenamid	5.00	4.00	0.2000
Disulfoton	10.00	6.80	0.6800
Ethylene dibromide	5.00	23.24	1.1620
Dichloropropane	5.00	54.43	2.7215
VIRGINIA—20 SITES—Continued			
Malathion	5.00	0.95	0.0475
Methoxychlor	5.00	1.00	0.0500
Ethyl parathion	5.00	6.00	0.3000
Phorate	5.00	3.00	0.1500
Sulfur	5.00	57.00	2.8500
Vernolate	5.00	2.40	0.1200
WASHINGTON—2 SITES			
Ceresan L	50.00	0.01	0.0050
2,4-D	50.00	1.00	0.5000
WEST VIRGINIA—5 SITES			
Azinphosmethyl	20.00	0.50	0.1000
Ethyl parathion	20.00	1.50	0.3000
WISCONSIN—68 SITES			
Atrazine	29.41	2.61	0.7664
Ceresan red	1.47	0.01	0.0001
2,4-D	2.94	0.75	0.0221
Ramrod	1.47	2.00	0.0294
Trifluralin	1.47	2.00	0.0294

NOTE: Of the 43 States with cropland soil analyzed, use records for 4 showed no pesticides used on the sampling sites: Nevada (2 sites); New Hampshire (2 sites); Vermont (5 sites); and Wyoming (17 sites).

TABLE 11.—*Summary of pesticides used in FY 1969 on noncropland, by State*

Compound	Percent of Sites Treated	Average Application Rate Per Site Treated (lb/acre)	Average Amount Applied Per Site (lb/acre)
GEORGIA—15 SITES			
Mirex	6.67	0.01	0.0007
IDAHO—26 SITES			
Malathion	3.85	0.61	0.0235
NEBRASKA—19 SITES			
2,4-D	5.26	2.00	0.1053

NOTE: Of the 11 States with noncropland soil analyzed, 8 reported no pesticides used on the sampling sites: Arizona (43 sites); Iowa (7 sites); Maine (11 sites); Maryland (3 sites); Virginia (14 sites); Washington (11 sites); West Virginia (9 sites); and Wyoming (37 sites).

TABLE 12.—*Comparison of residues detected with use records for 12 States with highest arsenic residues, FY 1969*

STATE	AVERAGE AMOUNT APPLIED (LB/ACRE)	PERCENT OF SITES TREATED	MEAN RESIDUE LEVEL (PPM)	PERCENT POSITIVE SITES[1]
Arkansas	[3] 0.13	4.4	9.0	100.0
Kentucky	No Arsenic Compounds Used		8.4	100.0
New England[2]	[4] 0.88	10.0	10.2	100.0
New York	[5] 0.12	5.3	9.4	94.6
North Dakota	No Arsenic Compounds Used		8.5	100.0
Ohio	No Arsenic Compounds Used		11.2	100.0
Pennsylvania	[4] 0.08	3.2	10.8	100.0

[1] Percent based on number of sites with residues greater than or equal to the sensitivity limits.

[2] Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.

[3] Calculated for DSMA.

[4] Calculated for sodium arsenite.

[5] Calculated for sodium arsenite and lead arsenate.

TABLE 13.—*Comparison of residues detected with use records for 5 States with highest DDTR residues, FY 1969*

STATE	AVERAGE AMOUNT APPLIED (LB/ACRE)	PERCENT OF SITES TREATED	MEAN RESIDUE LEVEL (PPM)	PERCENT POSITIVE SITES[1]
Alabama	4.20	39.1	1.13	90.9
California	0.38	13.6	1.47	84.6
Michigan	0.03	2.0	2.09	23.5
Mississippi	1.07	31.0	2.06	89.7
South Carolina	0.72	29.4	1.17	68.2

[1] Percent based on number of sites with residues greater than or equal to the sensitivity limits.

TABLE 14.—*Comparison of residues detected with use records for 7 States with highest dieldrin residues, FY 1969*

STATE	AVERAGE AMOUNT APPLIED (LB/ACRE)	PERCENT OF SITES TREATED	MEAN RESIDUE LEVEL (PPM)	PERCENT POSITIVE SITES[1]
Florida	0.00	0.0	0.08	38.9
Illinois	0.29 aldrin 0.01 dieldrin	19.2 2.1	0.11	61.3
Iowa	0.06 aldrin <0.01 dieldrin	8.6 0.7	0.06	53.6
Kentucky	0.19 aldrin	9.7	0.06	54.8
North Carolina	0.12 aldrin 0.09 dieldrin	6.9 6.9	0.08	32.3
Virginia/West Virginia	0.00	0.0	0.07	25.9

[1] Percent based on number of sites with residues greater than or equal to the sensitivity limits.

TABLE 15.—*Fiftieth percentile value for pesticide residues in cropland soil including the 95% confidence interval by State*

Pesticide	Upper Limit (ppm)	Fiftieth Percentile Residue Level (ppm)	Lower Limit (ppm)
ALABAMA			
Arsenic	4.42	4.09	3.76
p,p'-DDE	0.10	0.07	0.04
o,p'-DDT	0.03	0.02	0.01
p,p'-DDT	0.27	0.21	0.15
DDTR	0.48	0.38	0.29
p,p'-TDE	0.02	0.01	0.01
ARKANSAS			
Arsenic	7.42	7.26	7.10
p,p'-DDE	0.02	0.02	0.02
o,p'-DDT	0.01	0.01	0.00
p,p'-DDT	0.04	0.03	0.03
DDTR	0.10	0.09	0.08
Dieldrin	0.00	0.00	0.00
p,p'-TDE	0.01	0.01	0.01
Toxaphene	0.15	0.04	0.00
CALIFORNIA			
Arsenic	4.02	3.92	3.83
o,p'-DDE	0.00	0.00	0.00
p,p'-DDE	0.05	0.04	0.04
o,p'-DDT	0.01	0.01	0.00
p,p'-DDT	0.04	0.03	0.03
DDTR	0.14	0.13	0.12
Dieldrin	0.00	0.00	0.00
o,p'-TDE	0.00	0.00	0.00
p,p'-TDE	0.02	0.01	0.01
Toxaphene	0.02	0.01	0.00
COLORADO			
Arsenic	4.26	4.20	4.15
FLORIDA			
Arsenic	0.64	0.58	0.53
Chlordane	0.05	0.03	0.02
p,p'-DDE	0.03	0.02	0.01
o,p'-DDT	0.01	0.00	0.00
p,p'-DDT	0.07	0.05	0.03
DDTR	0.10	0.08	0.06
p,p'-TDE	0.02	0.01	0.00
GEORGIA			
Arsenic	1.96	1.88	1.80
p,p'-DDE	0.06	0.05	0.04
o,p'-DDT	0.01	0.01	0.01
p,p'-DDT	0.17	0.01	0.09
DDTR	0.30	0.23	0.17
p,p'-TDE	0.01	0.01	0.01
Toxaphene	0.36	0.28	0.18
IDAHO			
Arsenic	2.85	2.53	2.21
p,p'-DDT	0.00	0.00	0.00
DDTR	0.01	0.00	0.00
ILLINOIS			
Aldrin	0.00	0.00	0.00
Arsenic	6.28	6.20	6.13
Chlordane	0.01	0.01	0.00
DDTR	0.00	0.00	0.00
Dieldrin	0.03	0.02	0.02
Heptachlor	0.00	0.00	0.00
Heptachlor epoxide	0.00	0.00	0.00
INDIANA			
Aldrin	0.00	0.00	0.00
Arsenic	7.24	7.03	6.82
Dieldrin	0.00	0.00	0.00
IOWA			
Aldrin	0.00	0.00	0.00
Arsenic	5.86	5.78	5.71
Atrazine	0.01	0.00	0.00
Chlordane	0.01	0.01	0.00
p,p'-DDE	0.00	0.00	0.00
p,p'-DDT	0.00	0.00	0.00
DDTR	0.00	0.00	0.00
Dieldrin	0.02	0.01	0.01
Heptachlor	0.00	0.00	0.00
Heptachlor epoxide	0.00	0.00	0.00
KENTUCKY			
Aldrin	0.00	0.00	0.00
Arsenic	8.45	7.89	7.30
Dieldrin	0.01	0.01	0.00
LOUISIANA			
Arsenic	1.80	1.65	1.51
p,p'-DDE	0.01	0.00	0.00
o,p'-DDT	0.01	0.00	0.00
p,p'-DDT	0.02	0.01	0.00
DDTR	0.02	0.01	0.01
Dieldrin	0.01	0.01	0.00
MICHIGAN			
Arsenic	4.92	3.83	2.93
p,p'-DDE	0.00	0.00	0.00
DDTR	0.00	0.00	0.00
Dieldrin	0.00	0.00	0.00

TABLE 15.—*Fiftieth percentile value for pesticide residues in cropland soil including the 95% confidence interval by State*—Continued

PESTICIDE	UPPER LIMIT (PPM)	FIFTIETH PERCENTILE RESIDUE LEVEL (PPM)	LOWER LIMIT (PPM)
MID-ATLANTIC STATES GROUP [1]			
Arsenic	5.87	5.34	4.83
MISSISSIPPI			
Arsenic	4.86	4.68	4.51
p,p'-DDE	0.11	0.09	0.08
o,p'-DDT	0.06	0.06	0.05
p,p'-DDT	0.36	0.29	0.24
DDTR	0.67	0.55	0.45
p,p'-TDE	0.03	0.02	0.01
Toxaphene	0.24	0.16	0.09
MISSOURI			
Aldrin	0.00	0.00	0.00
Arsenic	5.43	5.05	4.69
Dieldrin	0.00	0.00	0.00
NEBRASKA			
Arsenic	4.73	4.56	4.40
Chlordane	0.01	0.00	0.00
p,p'-DDE	0.00	0.00	0.00
DDTR	0.00	0.00	0.00
Dieldrin	0.00	0.00	0.00
NEW ENGLAND STATES GROUP [2]			
Arsenic	6.39	5.71	5.09
p,p'-DDE	0.02	0.01	0.00
p,p'-DDT	0.05	0.02	0.00
DDTR	0.04	0.02	0.01
p,p'-TDE	0.01	0.01	0.00
NEW YORK			
Arsenic	6.34	6.12	5.90
p,p'-DDE	0.00	0.00	0.00
o,p'-DDT	0.00	0.00	0.00
p,p'-DDT	0.01	0.00	0.00
DDTR	0.00	0.00	0.00
Dieldrin	0.00	0.00	0.00
p,p'-TDE	0.00	0.00	0.00
NORTH CAROLINA			
Arsenic	3.42	3.07	2.77
p,p'-DDE	0.03	0.03	0.02
o,p'-DDT	0.02	0.01	0.01
p,p'-DDT	0.05	0.03	0.02
DDTR	0.18	0.13	0.08
Dieldrin	0.01	0.00	0.00
o,p'-TDE	0.03	0.02	0.01
NORTH CAROLINA—Continued			
p,p'-TDE	0.03	0.02	0.01
Toxaphene	0.16	0.07	0.01
NORTH DAKOTA			
Arsenic	6.82	6.79	6.75
p,p'-DDT	0.00	0.00	0.00
DDTR	0.00	0.00	0.00
OHIO			
Aldrin	0.00	0.00	0.00
Arsenic	7.85	7.58	7.32
DDTR	0.00	0.00	0.00
Dieldrin	0.00	0.00	0.00
OKLAHOMA			
Arsenic	2.19	2.11	2.02
PENNSYLVANIA			
Arsenic	7.22	6.65	6.15
p,p'-DDE	0.00	0.00	0.00
p,p'-DDT	0.00	0.00	0.00
DDTR	0.00	0.00	0.00
Dieldrin	0.01	0.00	0.00
p,p'-TDE	0.00	0.00	0.00
SOUTH CAROLINA			
Arsenic	1.98	1.82	1.68
p,p'-DDE	0.08	0.06	0.03
o,p'-DDT	0.04	0.03	0.02
p,p'-DDT	0.18	0.13	0.08
DDTR	0.31	0.15	0.06
p,p'-TDE	0.06	0.04	0.02
SOUTH DAKOTA			
Arsenic	3.86	3.76	3.68
Dieldrin	0.00	0.00	0.00
TENNESSEE			
Arsenic	7.18	7.00	6.81
p,p'-DDE	0.00	0.00	0.00
p,p'-DDT	0.01	0.00	0.00
DDTR	0.01	0.01	0.00

TABLE 15.—*Fiftieth percentile value for pesticide residues in cropland soil including the 95% confidence interval by State*—Continued

Pesticide	Upper Limit (ppm)	Fiftieth Percentile Residue Level (ppm)	Lower Limit (ppm)
VIRGINIA AND WEST VIRGINIA			
Arsenic	2.90	2.72	2.56
p,p'-DDT	0.01	0.00	0.00
DDTR	0.02	0.01	0.01
Heptachlor epoxide	0.01	0.00	0.00
WASHINGTON			
Arsenic	2.30	2.22	2.14
p,p'-DDT	0.00	0.00	0.00
DDTR	0.00	0.00	0.00
WESTERN STATES GROUP [3]			
Arsenic	3.57	3.40	3.23
p,p'-DDE	0.01	0.00	0.00
WESTERN STATES GROUP—Continued			
p,p'-DDT	0.00	0.00	0.00
DDTR	0.01	0.01	0.00
WISCONSIN			
Arsenic	3.33	3.14	2.97
DDTR	0.00	0.00	0.00
Dieldrin	0.00	0.00	0.00
WYOMING			
Arsenic	0.92	0.85	0.78

[1] Includes Delaware, Maryland, and New Jersey.

[2] Includes Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.

[3] Includes Arizona, Nevada, New Mexico, and Utah.

TABLE 16.—*Mean pesticide residues in ppm in soil for various cropping regions, FY 1969*

Compound	Corn	Cotton	Cotton and General Farming	General Farming	Hay and General Farming	Irrigated Land	Small Grains	Vegetable	Vegetable and Fruit
Aldrin	0.05	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	0.01
Arsenic	7.44	6.72	4.88	5.35	6.42	4.77	5.70	8.75	3.27
Atrazine	0.02						<0.01		
Carbophenothion			—	—		—			
Chlordane	0.09	<0.01	0.01	0.01	0.03	0.03	<0.01	<0.01	0.14
2,4-D				<0.01			<0.01	—	
DCPA	—	—	—	—	—	<0.01	—	—	—
o,p'-DDE	<0.01	0.01	<0.01	<0.01	<0.01	0.01	—	<0.01	0.01
p,p'-DDE	0.01	0.16	0.13	0.07	0.05	0.18	<0.01	0.18	0.37
o,p'-DDT	0.01	0.09	0.04	0.05	0.03	0.05	<0.01	0.07	0.06
p,p'-DDT	0.06	0.54	0.22	0.25	0.20	0.19	<0.01	0.50	0.64
DDTR	0.14	0.87	0.44	0.43	0.30	0.48	<0.01	0.81	1.92
DEF	—	—	—	<0.01	—	—	—	—	—
Diazinon		—	—			0.01			
Dicofol	<0.01	—	—	—	<0.01	0.01	—	—	—
Dieldrin	0.05	0.01	<0.01	0.03	0.02	0.02	<0.01	0.05	0.04
Endosulfan (I)	<0.01	—	—	—	<0.01	<0.01	—	—	—
Endosulfan (II)	<0.01	—	—	—	<0.01	0.01	—	<0.01	—
Endosulfan sulfate	<0.01	—	—	—	<0.01	0.01	—	<0.01	—
Endrin	<0.01	0.01	<0.01	<0.01	—	0.01	<0.01	0.01	0.01
Endrin aldehyde	—	—	—	—	—	—	—	—	<0.01
Endrin ketone	—	<0.01	<0.01	—	—	<0.01	—	<0.01	<0.01
Ethion		—	—			<0.01			
Ethyl parathion		—	—	<0.01	—	<0.01			
Heptachlor	0.01	—	<0.01	<0.01	<0.01	<0.01	—	—	<0.01
Heptachlor epoxide	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Isodrin	<0.01	—	—	<0.01	—	—	—	—	—
Lindane	<0.01	—	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	—
Malathion		—	—			—			
Methoxychlor	—	—	—	—	—	—	—	<0.01	—
PCNB	—	—	—	<0.01	—	—	—	—	—
o,p'-TDE	<0.01	<0.01	<0.01	0.01	<0.01	0.01	—	0.01	0.15
p,p'-TDE	0.05	0.07	0.04	0.04	0.01	0.04	<0.01	0.05	0.70
Toxaphene	<0.01	0.42	0.20	0.16	—	0.14	—	0.01	0.08
Trifluralin	<0.01	0.01	<0.01	<0.01	—	0.01	<0.01	<0.01	<0.01

NOTE: Blank = not analyzed; — = not detected.

TABLE 17.—*Percent of sites with detectable pesticide residues in ppm in soil for various cropping regions, FY 1969*

COMPOUND	CORN	COTTON	COTTON AND GENERAL FARMING	GENERAL FARMING	HAY AND GENERAL FARMING	IRRIGATED LAND	SMALL GRAINS	VEGETABLE	VEGETABLE AND FRUIT
Aldrin	23.5	6.4	0.9	6.6	2.1	6.5	0.6	1.1	3.0
Arsenic	100.0	100.0	98.4	99.4	99.3	99.1	99.4	98.9	93.9
Atrazine	14.5						8.3		
Carbophenothion			—	—	—	—			
Chlordane	14.5	1.8	2.6	7.2	5.5	11.1	0.9	4.3	21.2
2,4-D				14.3			1.7	—	
DCPA	—	—	—	—	—	0.9	—	—	—
o,p'-DDE	0.5	15.6	5.2	10.8	2.8	19.4	—	5.3	15.1
p,p'-DDE	9.5	69.7	44.8	46.4	21.4	58.3	5.8	38.3	60.6
o,p'-DDT	3.0	51.4	25.0	27.1	10.3	33.3	3.0	23.4	36.4
p,p'-DDT	7.7	66.1	43.1	42.2	16.5	53.7	5.8	31.9	57.6
DDTR	10.9	72.5	47.4	49.4	22.8	60.2	6.1	39.4	63.6
DEF	—	—	—	0.6	—	—	—	—	—
Diazinon		—	—			12.5			
Dicofol	0.6	—	—	—	0.7	5.6	—	—	—
Dieldrin	41.8	24.8	14.7	25.3	15.2	39.8	7.0	23.4	21.2
Endosulfan (I)	0.3	—	—	—	0.7	1.8	—	—	—
Endosulfan (II)	0.2	—	—	—	0.7	5.6	—	1.1	—
Endosulfan sulfate	0.3	—	—	—	1.4	5.6	—	1.1	—
Endrin	0.3	7.3	2.6	3.6	—	11.1	0.9	3.2	6.1
Endrin aldehyde	—	—	—	—	—	—	—	—	3.0
Endrin ketone	—	2.8	0.9	—	—	2.8	—	1.1	3.0
Ethion		—	—			6.3			
Ethyl parathion		—	—	10.0	—	12.5			
Heptachlor	8.6	—	1.7	1.8	1.4	0.9	—	—	3.0
Heptachlor epoxide	13.3	0.9	3.4	7.5	4.1	13.0	0.9	4.3	12.1
Isodrin	1.2	—	—	1.8	—	—	—	—	—
Lindane	0.3	—	2.6	1.2	0.7	1.8	0.6	3.2	—
Malathion		—	—			—			
Methoxychlor	—	—	—	—	—	—	—	1.1	—
PCNB	—	—	—	0.6	—	—	—	—	—
o,p'-TDE	0.3	0.9	2.6	10.8	2.1	13.0	—	5.3	6.1
p,p'-TDE	3.3	47.7	25.9	35.5	11.7	38.0	1.8	27.7	45.4
Toxaphene	0.2	22.9	12.1	10.2	—	12.0	—	1.1	6.1
Trifluralin	2.0	12.8	7.8	6.0	—	9.3	0.3	2.1	3.0

NOTE: Blank = not analyzed; — = not detected.

APPENDIX G

PESTICIDE PROPERTIES: PERSISTENCE, SOLUBILITY, LEACHABILITY, RUNOFF

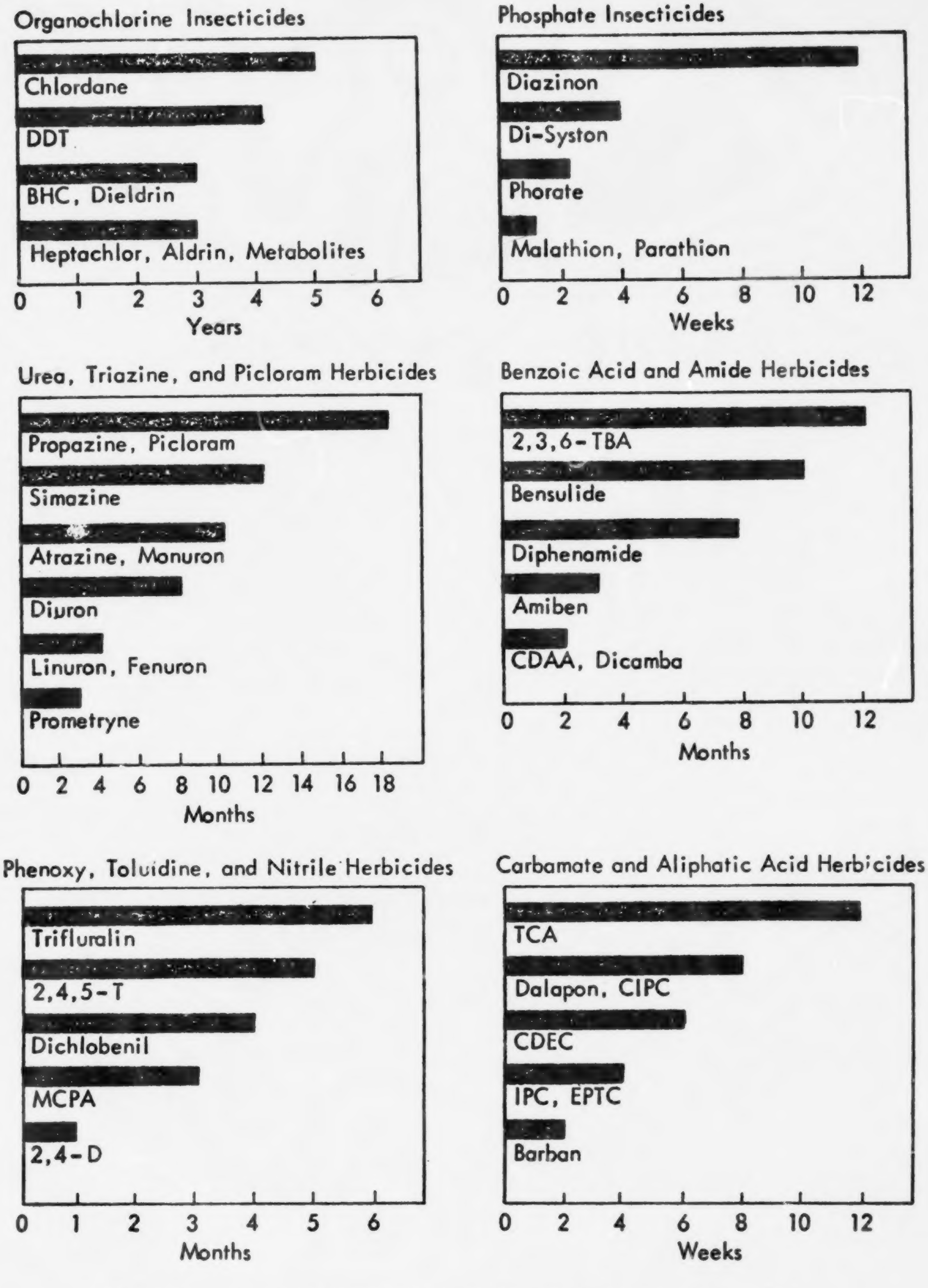

Figure G-1. Persistence of individual pesticides in soils.

Source: Kearney, P. C., and C. S. Helling, "Reactions of Pesticides in Soils," Residue Reviews, Vol. 25 (1969).

Table G-1. PERSISTENCE OF PESTICIDES AND THEIR DEGRADATION PRODUCTS IN SOIL

Pesticide and Degradation Products	Application Rate	Type of Soil or Water	Persistence Time	Comments
Organochlorine Insecticides:				
Chlordane	10 μg/liter	Natural river water	20 to 8 weeks	85% remains
	Six rates ranging 0.625 to 20 lb/acre	Loam soil	14.3 months	50% remains
		Soils	9 to 13 years	25% remains
	Normal rates	Normal agricultural soils	5 years	25 to 0% remains
	10 lb/acre/year	Sandy clay soil	4 years	Half life
	1 to 2 lb/acre	Soils	1 to 6 years	5% remains
DDT	20 lb/acre/year	Sandy clay soil	4 years	Half life
	1 to 2-1/2 lb/acre	Soils	4 to 30 years	5% remains
	10 lb/acre	Silt loam soil	15 years	10.6% remains
	1 lb/acre	Maine forest soil	30 years	Persistence
		Soil	4 years	22% remains
	100 ppm	Sandy loam	17 years	39% remains
	High rate	Soil	3 years	36% remains
	Normal	Normal agricultural soils	4 years	25 to 0% remains
	10 to 20 lb/acre	Soil	> 4 years	Persistence
	10 to 20 lb/acre	Soil	> 10 years	Persistence
	25 lb/acre	85 soil types	8 years	44% remains
Endosulfan	2 lb/acre	Soil	96 days	No detectable amounts remain

Table G-1. (Continued)

Pesticide and Degradation Products	Application Rate	Type of Soil or Water	Persistence Time	Comments
Toxaphene	20 lb/acre/year	Sandy clay soil	4 years	Half life
	140 ppm	Soil	> 6 years	Persistence
	50 ppm	Sandy loam	11 years	50% remains
	100 ppm	Sandy loam	14 years	45% remains
Organophosphorus Insecticides:				
Carbophenothion	2 to 4 lb/acre	Fine sandy soil	6 to 8 months	5% remains
Diazinon		Different types of soils	20 weeks	< 8% remains
	3 lb/acre	Soil	26 weeks	Persistence
		Soil	≤ 40 days	Very low levels remain
	High application rates	Submerged tropical soil	50 to 70 days	6 to 2% remains
	Normal	Normal agricultural soils	12 weeks	25 to 0% remains
		Sandy loam soil	1 month	~ 5% remains
	2 kg/hectare	Loam soil	10 months	5% remains
	2 to 4 lb/acre	Fine sandy soil	6 to 8 months	< 10% remains
Dimethoate	3 µg/liter	Silt loam soil, sandy loam soils	1 month	30% remains
	2 kg/hectare	Loam soil	2 months	25% remains
	4 to 6 lb/acre	Fine sandy soil	2 to 3 months	< 10% remains
Ethion	2 to 6 lb/acre	Fine sandy soil	6 to 8 months	43 to 23% remains
Guthion	50 lb/acre	Loam soil	5 months	64 to 13% remains
Malathion	Normal	Normal agricultural soils	1 week	25 to 0% remains

Table G-1. (Continued)

Pesticide and Degradation Products	Application Rate	Type of Soil or Water	Persistence Time	Comments
	5 lb/acre	Silt loam soil	8 days	3.1% remains
Methyl parathion	20 mg/kg	Sand-clayey soil	7 to 11 days	Complete decomposition
Parathion	31.4 lb/acre	Sandy loam soil	4 years	3% remains
	31.4 lb/acre	Sandy loam soil	16 years	0.1% remains
	1 lb/acre	Silty clay loam soil	2 months	No detectable amounts
		Soil	5 years	Persistence
	5 lb/acre	Silt loam soil	3 months	3% remains
	Normal	Normal agricultural soils	1 week	Persistence
		Sandy loam soil	4 weeks	< 5% remains
Paraoxon	20 ppm	Silt loam soil	1 day	< 10% remains
p-Nitrophenol	20 ppm	Silt loam soil	16 days	No residues detected
Aminoparathion	20 ppm	Silt loam soil	2 days	No residues detected
Phorate	3 μg/g	Silt loam soil and sandy loam soil	1 month	Complete breakdown
	10 ppm	Sandy loam soil	68 days	50% remains
	Normal	Normal agricultural soils	2 weeks	25 to 0% remains
	2 to 8 lb/acre	Sandy loam soil	1 to 2 weeks	< 2% remains
		Fine sandy soil	2 months	< 12% remains
Herbicides:				
Amitrole	2 to 10 lb/acre	Moist loam field soil	3 to 5 weeks	Persistence
		Soil	30 days	20% remains

Table G-1. (Continued)

Pesticide and Degradation Products	Application Rate	Type of Soil or Water	Persistence Time	Comments
	20 ppm	Soil	7 weeks	Persistence
	3 to 18 lb/acre	Soil	1 to 3 months	Residual phytotoxicity
	8.9 lb/acre	Soil	4 to 5 months	Residual phytotoxicity
Atrazine	2 to 10 kg/hectare	Loam soil	4 months	32 to 62% remains
	1 to 100 ppm	Four Hawaiian soils	34 days	15 to 30% remains
	1 and 2 lb/acre	Soils	> 200 days	Persistence
	Normal	Normal agricultural soils	10 months	25 to 0% remains
	2 lb/acre	Soil	17 months	Persistence
	2 to 4 lb/acre	Soil	4 to 7 months	Residual phytotoxicity
	2 to 3 lb/acre	Soil	4 to 7 months	Residual phytotoxicity
	3 to 8 lb/acre	Soil	12 months	Residual phytotoxicity
	3.2 to 4 lb/acre	Soil	4 to 8 months	Residual phytotoxicity
2,4-D	Normal	Normal agricultural soils	1 month	25 to 0% remains
	0.5 to 3 lb/acre	Moist loam soil	1 to 4 weeks	Persistence
	4 lb/acre	Peat soils	4 to 18 weeks	Persistence
	3.6 lb/acre	Clay loam soil	2 months	Persistence
	10 lb/acre	Several soil type	2 to 14 weeks	Persistence
	1.5 kg/hectare	Podsolic soil	2 to 7 weeks	Complete detoxification

Table G-1. (Continued)

Pesticide and Degradation Products	Application Rate	Type of Soil or Water	Persistence Time	Comments
	Average	Soil	1 month	Persistence
	4 to 40 lb/acre	Soils	1 month	Residual phytotoxicity
	5 lb/acre	Soils	1 month	Residual phytotoxicity
Dacthal	Recommended rates	Most soil types	100 days	Average half life
Dalapon	50 ppm	43 different California soils	Range from 2 to 8 weeks	Total disapperance to 66% remaining
		Soils	5 weeks	No phytotoxicity
	50 ppm	Different types of soils (20 to 27% moisture)	4 to 5 weeks	No residue remains
	Normal	Normal agricultural soils	8 weeks	25 to 0% remains
	5 to 40 lb/acre	Moist loam field soil	10 to 60 days	Persistence
	7.4 to 20 lb/acre	Soils	1 month	Residual phytotoxicity
	20 lb/acre	Soils	3 to 4 months	Residual phytotoxicity
	6 to 8 lb/acre	Soils	1 to 2 months	Residual phytotoxicity
Diphenamid	Recommended rates	Most soil types	3 to 6 months	Average persistence
	Normal	Normal agricultural soils	8 months	25 to 0% remains
	3 to 4 lb/acre	Soils	10 to 12 months	Residual phytotoxicity
	3 lb/acre	Soils	3 months	Residual phytotoxicity
	3.75 lb/acre	Soils	< 3 months	Residual phytotoxicity

Table G-1. (Continued)

Pesticide and Degradation Products	Application Rate	Type of Soil or Water	Persistence Time	Comments
Diuron	Normal	Normal agricultural soils	8 months	25 to 0% remains
	1 to 3 lb/acre	Moist loam field soil	3 to 6 months	Persistence
	10 to 40 lb/acre	Moist loam field soil	6 to 24 months	Persistence
	1 to 2 lb/acre	Clay loam and silt loam soils	18 to 20 weeks	Persistence
	3.6 to 4 lb/acre	Soils	5 to 7 months	Residual phyto-toxicity
	1 to 2 lb/acre	Soils	4 to 8 months	Residual phyto-toxicity
	2 lb/acre	Soils	15 months	Residual phyto-toxicity
DNBP	6 to 9 lb/acre	Moist loam field soil	3 to 5 weeks	Persistence
	16 lb/acre	Soil	4 to > 8 weeks	Persistence
	8 lb/acre	Soil	6 months	Residual phyto-toxicity
	12 lb/acre	Soil	> 5 months	Residual phyto-toxicity
	0.05 lb/acre	Soil	> 3 months	Residual phyto-toxicity
DMOC	4 kg/hectare	Soil	28 weeks	< 0.01 ppm remains
	50 ppm	Soil	7 days	Persistence
MCPA	1/2 to 3 lb/acre	Mosit loam field soil	1 to 4 weeks	Persistence
	Normal	Normal agricultural soil	3 months	25 to 0% remains
Pyrazon	4 ppm	Soil	6 to 7 months	Almost disappeared

Table C-1. (Continued)

Pesticide and Degradation Products	Application Rate	Type of Soil or Water	Persistence Time	Comments
	Recommendation rates	Soils	3 to 6 months	Average persistence
Simazine	3.6 lb/acre	Clay loam soil	60 days	Persistence
	1 to 4 lb/acre	Moist loam field soil	3 to 6 months	Persistence
	10 to 40 lb/acre	Moist loam field soil	6 to 24 months	Persistence
	2 lb/acre	Soil	17 months	Persistence
		Soil	24 weeks	15% activity remains
	3 kg/hectare	Soil	11 weeks	Total decomposition
	Normal	Normal agricultural soil	1 year	25 to 0% remains
	2 to 5 lb/acre	Soil	12 months	Residual phytotoxicity
	0.45 to 4.5 lb/acre	Soil	3 to 7 months	Residual phytotoxicity
	4 lb/acre	Soil	18 months	Residual phytotoxicity
	3.2 to 4.0 lb/acre	Soil	4 to 14 months	Residual phytotoxicity
Sodium arsenite	Recommendation rates	Soils	5 years	Phytotoxicity
Sodium chlorate	450 to 1,200 lb/acre	Moist loam field soil	6 to 12 months	Persistence
	300 lb/acre	Soil	> 1 year	Persistence
Sutan	Recommendation rates	Several soils	1.5 to 3 weeks	Half life
TCA	15 lb/acre	Soil	42 to 64 days	Persistence
		Soils	5 weeks	No phytotoxicity

Table G-1. (Concluded)

Pesticide and Degradation Products	Application Rate	Type of Soil or Water	Persistence Time	Comments
	40 to 100 lb/acre	Moist loam field soil	50 to 90 days	Persistence
	Normal	Normal agricultural soil	12 weeks	25 to 0% remains
	8 to 60 lb/acre	Soils	1 to 3 months	Residual phytotoxicity
	12.5 to 67 lb/acre	Soils	7 to 12 months	Residual phytotoxicity
	16 to 30 lb/acre	Soils	4 months	Residual phytotoxicity
Trifluralin	1 and 2 lb/acre	Soils	> 200 days	Persistence
	0.75 lb/acre	Soils	10 to 12 months	10 to 15% remains
	Normal	Normal agricultural soils	6 months	25 to 0% remains
Other Pesticides:				
Captan (fungicide)		Fumus sandy soils	3 weeks	Half decay value
	Well distributed in soil	Soil	1 to 2 days	Half life
		Soil	65 days	Persistence
Naban (fungicide)	100 ppm	Soil	> 20 days	Persistence
Ziram (fungicide)		Soil	> 35 days	Persistence

Source: "The Effects of Agricultural Pesticides in the Aquatic Environment," Irrigated Croplands, San Joaquin Valley, Office of Water Programs, Environment, American Chemical Society, Washington, D.C.

Table C-2. PESTICIDE PROPERTIES

Pesticide	Solubility		Volatilization index	Leaching index	Surface runoff		Degradation	Persistence	Carry-over
	(ppm) at	(°C)			Water	Sed.			
Alachlor	210	30	3	1.5	minor	minor	rapid	little	none
Propanil	140	30	2	1.5	neg	neg	1-2 days	little	none
Trifluralin	< 1		2	1.5	no	low	80%/yr	moderate	possible
Dalapon - Na	500,000		1	4	yes	yes	60 days	little	no
MPCA	825	30	1	2	yes	yes	rapid	4-6 weeks	0
2,4-D	620	30	1	2	yes	yes	rapid	4 weeks	0
2,4,5-T	278	30	1	2	yes	yes	f. rapid	3 months	0
Carbaryl	NA	30	3.5	2	low	low	mod.-rapid	λ = 7-10 days	0
Malathion	120	30	2	2.5	low	poss.	rapid	< 2 weeks	0
Naled	2,000		4	3	poss.	low	v. rapid	λ = 4 hr	0
Dimethoate	50,000	30	2	2.5	high	poss.	low in water	3-4 days	0
Fenthion	55	25	2	2	low	poss.	moderate	low, 4 months	0
Diazinon	40	20	3	2	poss.	poss.	mod. rapid	4-6 weeks	0
Ethion	2	22	1.5	1.5	low	poss.	rapid	90% in 30 days	0
Azinphos-methyl	25	30	NA	1.5	nil.	low	rapid	low	< 10%/yr
Phosphomidon	mis.	30	2.5	3.5	high	poss.	NA	NA	0
Mevinphos	mix.	30	3.5	3.5	high	nil.	rapid	3-12 hr	0
Methyl Parathion	25	20	3	2	low	low	v. rapid	not persist.	0
Parathion	9	20	3	2	low	poss.	moderate	not persist.	0
DDT	insol.		1	1	low	high	v. slow	v. persist.	v. high
BHC	10	20	3	1	nil.	minor	v. slow	v. persist.	yes
Chlordane	insol.		2	1	nil.	NA	slow	λ = 1 yr	yes
Heptachlor	0.01	20	3	1	nil.	NA	slow	λ = 1 yr	yes
Toxaphene	0.0.4	25	4	1	nil.	poss.	slow	v. persist.	poss.
Aldrin	0.011	20	1	1	no	high	slow	v. persist.	v. high
Dieldrin	0.11	20	1	1	no	high	slow	v. persist.	v. high
Endrin	0.16	20	1	1	no	low	slow	persist.	high
Captan	3.3	25	2	1	low	NA	rapid	λ = 2 weeks	0
Benomyl	0	20	3	2.5	no	no	NA	NA	NA
Zineb	v. slight		1	2	low	low	rapid	not	0
Maneb	v. slight		1	2	low	slight	NA	1-2 weeks	0
Mancozeb	v. slight		1	2	no	poss.	rapid	not	0
Methyl Bromide	slight		NA	nil	no	no	rapid	λ = 55 days	0

Source: Pesticide Manual, R. von Kümker and F. Morey, USAID, August 1972.

Volatilization Index

1 = volat. loss < 0.1 kg/ha/yr
2 = volat. loss 2
3 = volat. loss 5
4 = volat. loss > 10

Leaching Index

Distance of travel through loam soil profile under 150 cm/yr rainfall

1 = movement of < 10 cm
2 = movement of 10-20 cm
3 = movement of 20-30 cm
4 = movement of < 30 cm

Table G-3. SELECTED EXPERIMENTAL AND FIELD DATA ON PESTICIDE RESIDUES AND LOSSES IN RUNOFF

No.	Location and year	Pesticide used	Application rate (lb/acre)	Soil class	Maximum concentration in runoff after first storm (ppb)	Concentration in runoff after stated time (ppb)	% Loss of pesticide in sediment	% Loss (total)	Reference
1	North Carolina (1968)	2,4-D	-	-	1,882	-	-	-	Kearney[1]
		Picloram	-	-	4,187	-	-	-	
		2,4,5-T	-	-	681	-	-	-	
2	Baton Rouge, Louisiana	Endrin	-	Mhoon clay loam	1.06 (24 hr)	0.46 (72 hr)	-	-	Willis[1]
3	West, Texas	Trifluralin	-	Pullman	40	-	-	-	Axes[2]
		Propazine	-	Silty	50	-	-	-	
		Atrazine	-	Clay loam	40	-	-	-	
4	Coshocton, Ohio (1971-1972)	Dieldrin	5	Muskingham silt loam	20	4 (3 years)	2.20	2.27	Caro et al[4]
		Carbofuran (broadcast)	4.83	Muskingham silt loam	1,398 (25 days)	5 (239 days)	-	0.9	Caro et al[4]
		Carbofuran (band)	3.71	Muskingham silt loam	13,678 (28 days)	3 (119 days) 677 (30 days)	-	0.5	Caro et al[4]
5	Castana, Iowa (1967-1970)	Diazinon	1	-	82 (4 days)	-	-	0.1	Ritter et al[5]
		Propachlor	4	Surface contour	780 (7 days)	-	0.65	2.6	
					200 (37 days)	-	0	0.23	
		Propachlor	4	Ridge	-	-	-	~ 0	Ritter et al[5]
		Atrazine	3	Surface contour	4,910 (7 days)	-	3.4	14.0	Ritter et al[5]
		Atrazine	3	Ridge	-	-	0.15	2.0	Ritter et al[5]
6		Atrazine	2.2	Haggerstown silty clay	1,390	-	0.16	2.56	Hall[7]
					< 200 (1 month)	-	-	-	
7	Watkinsville, Georgia (1965)	Atrazine	3	Cecil sandy loam	700 (96 hr)	-	-	2.0	White et al[8]
8	Watkinsville, Georgia (1967)	2,4-D	2.2	Cecil sandy loam	-	-	-	4.0	Barnett[10]
9	Waynesville, North Carolina (1968-1970)	2,4-D	-	-	1,200	-	-	-	Sheets[3]
					1,900	-	-	-	
					2,500	-	-	-	
10	Dothan, Alabama	Atrazine (80%)	1.88	-	-	-	1.95	6.44	Bailey et al[5]
		Dichlobenil (50%)	12.0	-	-	-	0.36	2.72	
	Mobile, Alabama	Atrazine (80%)	3.76	-	-	-	1.93	13.3	Bailey et al[5]
		Dichlobenil (80%)	12.0	-	-	-	2.33	9.94	

Table G-3. (Concluded)

No.	Location and year	Pesticide used	Application rate (lb/acre)	Soil class	Maximum concentration in runoff after first storm (ppb)	Concentration in runoff after stated time (ppb)	% Loss of pesticide in sediment	% loss (total)	Reference
11	(1971)	Aldrin	1.5	Maury silt loam	20 (1 day)	20 (7 days)	7.3	11.0	Haan[9]
		Dieldrin	1.5	Maury silt loam	45 (1 day)	45 (7 days)	6.2	11.2	
		DDT	1.5	Maury silt loam	4 (1 day)	4 (7 days)	6.3	6.8	
12	(1965)	DDT	731 g/ha	-	82 (1 day)	-	-	1.39	Epstein and Grant[11]
	(1965)	Endrin	289 g/ha	-	50 (1 day)	-	-	0.85	
		Endosulfan	351 g/ha	-	2.2 (1 day)	-	-	0.35	

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APPENDIX H

STATISTICS OF DEICING SALT APPLICATION ON HIGHWAY AND TOLLWAYS IN THE UNITED STATES

Table H-1. APPLIED SALTS AND APPLICATION RATES TO HIGHWAYS AND TOLLWAYS IN THE UNITED STATES[a]

State	NaCl				$CaCl_2$			
	Applied Salt 1965-1966		Application Rate Per Snowday		Applied Salt 1965-1966		Application Rate Per Snowday	
	1,000 MT	1,000 tons	(kg/km)	(lb/mile)	(MT)	(tons)	(kg/km)	(lb/mile)
Northeastern States								
Maine	76.2	84.0	210	747	907	1,000	2.5	8.9
New Hampshire	75.0	82.7	221	787	490	540	1.4	5.1
Vermont	75.4	83.1	510	1,810	454	500	3.1	10.9
Massachusetts	109.1	120.3	401	1,422	5,312	5,855	19.5	69.2
Connecticut	67.7	74.6	299	1,058	7,258	8,000	31.9	113.0
Rhode Island	42.6	47.0	423	1,506	907	1,000	9.1	32.1
New York	222.5	245.3	187	665	3,538	3,900	3.0	10.6
Pennsylvania	292.1	322.0	182	647	31,265	34,463	19.5	69.2
New Jersey	15.9	17.5	176	625	2,899	3,195	32.1	114.0
Delaware	2.5	2.8	385	1,400	744	820	116.0	410.0
Maryland	40.7	44.9	471	1,675	422	465	4.9	17.4
Virginia	29.7	32.7	268	948	14,607	16,101	132.0	467.0
North-Central States								
Ohio	464.0	511.0	268	950	10,886	12,000	6.3	22.3
West Virginia	31.2	34.4	96	339	11,308	12,465	34.7	123.0
Kentucky	36.6	40.3	210	743	907	1,000	5.2	18.4
Indiana	101.0	111.3	499	1,772	4,130	4,552	20.4	72.5
Illinois	113.7	125.3	201	712	5,017	5,530	8.9	31.4
Michigan	122.7	135.3	162	576	3,341	3,683	4.4	15.7
Wisconsin	101.6	112.0	141	498	2,812	3,100	3.9	13.8
Minnesota	361.0	398.0	129	459	12,701	14,000	4.5	16.1
North Dakota	1.8	2.0	2	6	907	1,000	0.8	2.9

Table H-1. (Continued)

State	NaCl Applied Salt 1965-1966 1,000 MT	NaCl Applied Salt 1965-1966 1,000 tons	NaCl Application Rate Per Snowday (kg/km)	NaCl Application Rate Per Snowday (lb/mile)	$CaCl_2$ Applied Salt 1965-1966 (MT)	$CaCl_2$ Applied Salt 1965-1966 (tons)	$CaCl_2$ Application Rate Per Snowday (kg/km)	$CaCl_2$ Application Rate Per Snowday (lb/mile)
Southern States								
Arkansas	1.1	1.2			352	388		
Tennessee	N.A.							
North Carolina	15.0	16.5	410	1,447	1,610	1,775	44.0	156
Mississippi	0.9	1.0	170	606				
Alabama	N.A.				227	250		
Georgia	0.007	0.008	1	4	272	300	37.5	133
South Carolina	N.A.							
Louisiana	0.3	0.37			20	22		
Florida	0.0							
West-Central States								
Iowa	30.3	33.4	144	510	2,064	2,275	9.9	35
Missouri	9.9	10.9	27	97	1,674	1,845	4.5	16
Kansas	13.5	14.9	46	164	588	648	2.0	7
South Dakota	0.9	1.0	113[b]	400[b]	907	1,000	0.8	3
Nebraska	3.3	3.6	113[b]	400[b]	363	400	0.3	1
Colorado	4.1	4.5	53	188	136	150	1.7	6
Southwestern States								
Oklahoma	2.1	2.3	113[b]	400[b]	N.A.			
New Mexico	10.0	11.0	85	301	N.A.			
Texas	2.3	2.5	113[b]	400[b]	0.0			

Table H-1. (Concluded)

State	NaCl				CaCl$_2$			
	Applied Salt 1965-1966		Application Rate Per Snowday		Applied Salt 1965-1966		Application Rate Per Snowday	
	1,000 MT	1,000 tons	(kg/km)	(lb/mile)	(MT)	(tons)	(kg/km)	(lb/mile)
Western States								
Washington	2.1	2.3	6	20	36	40	0.1	0.3
Idaho	0.7	0.8	2	8	907	1,000	2.8	10
Montana	0.9	1.0	14	50	58	64	0.8	3
Oregon	0.6	0.7	1	4	150	165	0.3	1
Wyoming	0.6	0.7	2	6	145	160	0.3	1
California	18.1	20.0		1,320	N.A.			
Nevada	2.4	2.6	113[b]	400[b]	N.A.			
Utah	28.4	31.3	70	246	N.A.			
Arizona	0.1	0.1	113[b]	400[b]	9	10		
District of Columbia	25.5	28.1	2,802	10,040	41	45	4.5	16
Alaska	0.4	0.4	113[b]	400[b]	94	104		
Hawaii					0.0	0.0		

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[a] Sources: Field, R., E. J. Struzeski, Jr., H. E. Masters, and A. N. Tafuri, Water Pollution and Associated Effects from Street Salting, U.S. Environmental Protection Agency, Report EPA-R2-73-257, May 1973.
Hanes, R. E., L. W. Zelazny, and R. E. Blaser, Effects of Deicing Salts on Water Quality and Biota, Highway Research Board, National Cooperative Highway Research Program Report 91 (1970).

[b] Recommended application rate - Salt Institute.

N.A. - Not available.

Table H-2. MILEAGE OF TREATED HIGHWAYS AND TOLLWAYS, AND MEAN ANNUAL SNOWDAYS BY STATE

State	Single-Lane Kilometers Treated x 1,000[a]	Single-Lane Miles Treated x 1,000[a]	Mean Annual Snowdays[c]
Northeastern States			
Maine	12.1	7.5	30
New Hampshire	11.3	7.0	30
Vermont	7.4	4.6	20
Massachusetts	15.1	9.4	18
Connecticut	15.1	9.4	15
Rhode Island	8.4[b]	5.2[b]	12
New York	59.4	36.9	20
Pennsylvania	89.0	55.3	18
New Jersey	12.9	8.0	7
Delaware	1.3	0.8	5
Maryland	10.8	6.7	8
Virginia	22.2	13.8	5
North-Cental States			
Ohio	173.1[b]	107.6[b]	10
West Virginia	27.2	16.9	12
Kentucky	34.9	21.7	5
Indiana	25.3	15.7	8
Illinois	62.9	39.1	9
Michigan	37.8	23.5	20
Wisconsin	40.0	25.0	18
Minnesota	186.0[b]	115.6[b]	15
North Dakota	111.8[b]	69.5[b]	10
Southern States			
Arkansas	N.A.	N.A.	3
Tennessee	N.A.	N.A.	3
North Carolina	12.2	7.6	3
Mississippi	5.3	3.3	1
Alabama	0.1	0.1	1
Georgia	7.2	4.5	1
South Carolina	N.A.	N.A.	1
Louisiana	N.A.	N.A.	1
Florida	0.0	0.0	0

Table H-2. (Concluded)

State	Single-Lane Kilometers Treated x 1,000	Single-Lane Miles Treated x 1,000	Mean Annual Snowdays
West-Central States			
Iowa	21.1	13.1	10
Missouri	51.5	32.0	7
Kansas	41.7	25.9	7
South Dakota	96.9[b]	60.2[b]	10
Nebraska	123.9[b]	77.0[b]	10
Colorado	3.9	2.4	20
Southwestern States			
Oklahoma	N.A.	N.A.	3
New Mexico	11.7	7.3	10
Texas	N.A.	N.A.	3
Western States			
Washington	24.6	15.3	15
Idaho	16.1	10.0	20
Montano	3.2	2.0	20
Oregon	29.8	18.5	20
Wyoming	20.3	12.6	20
California	9.7	6.0	5
Nevada	N.A.	N.A.	10
Utah	20.4	12.7	20
Arizona	N.A.	N.A.	10
District of Columbia	1.3	0.8	7
Alaska	N.A.	N.A.	23
Hawaii	0.0	0.0	0

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a/ Source: Hanes, R. E., L. W. Zelazny, and R. E. Blaser, *Effects of Deicing Salts on Water Quality and Biota*, Highway Research Board, National Cooperative Highway Research Program Report 91 (1970).

b/ MRI estimates.

c/ Source: U.S. Department of the Interior, Geological Survey, *The National Atlas of the United States* (1970).

N.A. - Not available.